WEATHER CONTROL
AND
AUGMENTED POTABLE WATER SUPPLY

JOINT HEARINGS
BEFORE
SUBCOMMITTEES OF THE
COMMITTEES ON INTERIOR AND INSULAR AFFAIRS
INTERSTATE AND FOREIGN COMMERCE
AND
AGRICULTURE AND FORESTRY
UNITED STATES SENATE
EIGHTY-SECOND CONGRESS
FIRST SESSION
ON

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JUN 28 1951

S. 5
A BILL TO PROVIDE FOR RESEARCH INTO AND DEMONSTRATION OF PRACTICAL MEANS FOR THE ECONOMICAL PRODUCTION, FROM SEA OR OTHER SALINE WATERS, OR FROM THE ATMOSPHERE (INCLUDING CLOUD FORMATIONS), OF WATER SUITABLE FOR AGRICULTURAL, INDUSTRIAL, MUNICIPAL, AND OTHER BENEFICIAL CONSUMPTIVE USES, AND FOR OTHER PURPOSES

S. 222
A BILL TO PROVIDE FOR THE DEVELOPMENT AND REGULATION OF METHODS OF WEATHER MODIFICATION AND CONTROL

AND

S. 798
A BILL TO AUTHORIZE THE SECRETARY OF AGRICULTURE TO CONDUCT RESEARCH AND EXPERIMENTS WITH RESPECT TO METHODS OF CONTROLLING AND PRODUCING PRECIPITATION IN MOISTURE-DEFICIENT AREAS

WASHINGTON, D. C., MARCH 14, 15, 16, 19, AND APRIL 5, 1951

Printed for the use of the Committee on Interior and Insular Affairs, the Committee on Interstate and Foreign Commerce, and the Committee on Agriculture and Forestry

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WEATHER CONTROL AND AUGMENTED POTABLE WATER SUPPLY

WEDNESDAY, MARCH 14, 1951

UNITED STATES SENATE,
SUBCOMMITTEES OF THE COMMITTEES ON
INTERIOR AND INSULAR AFFAIRS,
INTERSTATE AND FOREIGN COMMERCE,
AGRICULTURE AND FORESTRY,
Washington, D. C.

The subcommittees met, pursuant to call, at 10:10 a. m., in room 224 Senate Office Building, Senator Clinton P. Anderson presiding.

Present: Senators Clinton P. Anderson, Lester C. Hunt, George A. Smathers, Guy Cordon, Arthur V. Watkins, and Francis Case.

Also present: Mills Astin, chief clerk to the Committee on Interior and Insular Affairs.

Senator ANDERSON. The committees will be in session.

Senator Hunt and I are chairmen of the subcommittees, one from Interior and Insular Affairs, one from Interstate and Foreign Commerce, and one from Agriculture and Forestry. We thought we would save a lot of time if we covered all three bills at the same time, S. 5, S. 222, and S. 798.

(S. 5, S. 222, and S. 798 are as follows:)

[S. 5, 82d Cong., 1st sess.]

A BILL To provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the acute shortage of water in the arid areas of the Nation and elsewhere and the excessive use of underground waters throughout the Nation, it is the policy of the Congress to provide for the development of economically feasible means of producing from sea water, from other saline waters, or from the atmosphere (including cloud formations) water of quality suitable for agricultural, industrial, municipal, and other beneficial consumptive uses. To this end, the Secretary of the Interior, acting through such agencies of the Department of the Interior as he may deem appropriate, is authorized to construct, maintain, and operate facilities (including not more than one demonstration plant) to determine and to demonstrate the feasibility of producing water as aforesaid and for purifying, storing, transporting, and distributing the water and byproducts derived from the operation of such facilities. Facilities constructed and operations undertaken pursuant to this Act shall be on a scale sufficient to determine the feasibility of the development of such production, transportation, and distribution, on a large-scale basis, for the purpose of conserving and increasing the water resources of the Nation.

SEC. 2. In order to carry out the purposes of this Act, the Secretary of the Interior is authorized—

(a) to conduct research and development work, and with the demonstration plant and other facilities to make careful engineering studies to ascertain the lowest investment and operating costs, and to determine the best plant designs and conditions of operation;

(b) to study methods for the recovery and marketing of byproducts resulting from and incident to the production of water as herein provided for the purpose of ascertaining the possibilities of offsetting the costs of water production in any area by the commercial utilization of such products;

(c) to acquire, by purchase, license, lease, or donation, secret processes, technical data, inventions, patent applications, patents, licenses, land and any interest in land (including water rights, easements, and leasehold interests), plants and facilities, and other property or rights: *Provided*, That the land or other property acquired hereunder shall not exceed that necessary to carry on the experiments and demonstrations for the purposes herein provided;

(d) to engage, by contract or otherwise, chemists, physicists, engineers, and such other personnel as may be deemed necessary, and any educational institution, scientific organization, or industrial or engineering firm deemed suitable to do any part of the research or other work;

(e) to cooperate with any other Federal, State, or municipal department, agency, or instrumentality, and with any private person, firm, educational institution, or other organization in effectuating the purpose of this Act;

(f) to request other Federal departments, agencies, and instrumentalities to provide assistance in carrying out his functions under this Act, which assistance such departments, agencies, and instrumentalities are hereby authorized to render, and to advance to them funds required to render such assistance or to reimburse them for costs incurred in so doing; and

(g) to pursue on the ground or, any provision of law or administrative regulation to the contrary notwithstanding, in the air operations for producing water from the atmosphere (including cloud formations).

SEC. 3. The Secretary of the Interior is authorized to dispose of all water and other products produced as a result of its operations under this Act pursuant to regulations to be prescribed by him: *Provided*, That any runoff resulting from precipitation created artificially under the authority granted in this Act shall be considered as a part of the natural stream flow and shall be available for use in the same manner as other natural accretions to the stream flow; and the Secretary shall have authority to grant, under such terms as he may consider appropriate, licenses under patent rights acquired under this Act: *Provided*, That such licenses are consistent with the terms of the agreements by which such patent rights are acquired. No patent acquired by the United States under this Act shall prevent any citizen of the United States, or corporation created under the laws of the United States or any State thereof, from using any invention, discovery, or process covered by such patent, or restrict such use by any such citizen or corporation, or be the basis of any claim against any such person or corporation on account of such use.

SEC. 4. All moneys received for products of the plants and for royalties and licenses under this Act shall be paid into the Treasury as miscellaneous receipts.

SEC. 5. The acts and omissions of any person or corporation who, in accordance with the terms of a contract with the United States entered into under the provisions of this Act, carries on operations for the artificial inducement of precipitation shall, with respect to third parties who are or may be adversely affected by precipitation so induced or by other meteorological phenomena caused by such inducement or attempts thereat, be deemed the acts and omissions of the United States and shall be governed by the law applicable to the same, and the Secretary of the Interior is hereby authorized to provide in any such contract that the United States shall indemnify the contractor against liability on account of claims (including reasonable expenses of litigation and, when approved in advance by the Secretary, compromise or settlement of such claims) made by third parties as hereinbefore described and any contract so providing shall also contain appropriate provisions for notice to the Government of suits or actions filed, or claims made, against the contractor with respect to any alleged liability to which the indemnification provisions relate and for control of or assistance in the defense of any such suit, action, or claim by the Government as its election.

SEC. 6. The Secretary of the Interior shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act. The report shall include suitable recommendations for further legislation.

SEC. 7. The Secretary of the Interior may issue rules and regulations to effectuate the purposes of this Act.

SEC. 8. There are authorized to be appropriated, from any funds in the Treasury not otherwise appropriated, such sums, not to exceed $25,000,000, as the Congress may from time to time deem necessary to carry out the provisions of this Act.

[S. 222, 82d Cong., 1st sess.]

A BILL To provide for the development and regulation of methods of weather modification and control.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Weather Control Act of 1951".

DECLARATION OF POLICY

SEC. 2. (a) FINDINGS AND DECLARATION.—Research and experimentation in the field of weather modification and control have attained the stage at which the application of scientific advances in this field appears to be practical. The effect of the use of measures for the control of weather phenomena upon the social, economic, and political structures of today, and upon national security, cannot now be determined. It is a field in which unknown factors are involved. It is reasonable to anticipate, however, that effective modification and control of weather will cause profound changes in our present way of life, and will result in vast and far-reaching benefits to agriculture, industry, commerce, and the general welfare and common defense. While the ultimate extent to which weather modification and control may be utilized is speculative, the application of such measures without proper safeguards, sufficient data, and accurate information may result in inadequate or excessive precipitation; may cause catastrophic droughts, storms, floods, and other phenomena with consequent loss of life and property, injury to navigable streams and other channels of interstate and foreign commerce, injury to water supplies for municipal, irrigation, and industrial purposes, and injury to sources of hydroelectric power; may otherwise impede the production and transportation of goods and services for domestic consumption and export and for the national defense; and may otherwise adversely affect the general welfare and common defense. Thorough experimentation and full-scale operations in weather modification and control will of necessity affect areas extending across State boundaries. The Congress therefore recognizes that experimentation and application of such measures are matters of national concern. Accordingly, it is hereby declared to be the policy of the Congress, in order to effect the maximum benefit which may result from experiments and operations designed to modify and control weather, to authorize such regulation and supervision as may be determined to be necessary or desirable of those who attempt to engage in such activity; to correlate and evaluate the information derived from such activity; and to cooperate with the several States and the duly authorized officials thereof with respect to such activity, all to the end of encouraging the intelligent experimentation and the beneficial development of weather modification and control, preventing its harmful and indiscriminate exercise, and fostering sound economic conditions in the public interest.

(b) PURPOSE OF ACT.—It is the purpose of this Act to effectuate the policies set out in subsection (a) by providing, among others, for the following major programs relating to weather modification and control:

(1) A program of assisting and fostering private research and development to encourage maximum scientific progress.

(2) A program of federally conducted research and development to assure the Government of adequate scientific and technical accomplishment.

(3) A program for Government control of experiments and operations in order to advance the general welfare, assure the common defense and national security, and promote the broadest possible exploitation of the fields.

(4) A program of administration which will be consistent with the foregoing policies and with international arrangements made by the United States, and which will enable the Congress to be currently informed so as to take further legislative action as may hereafter be appropriate.

ORGANIZATION

SEC. 3. (a) WEATHER CONTROL COMMISSION.—

(1) There is hereby established a Weather Control Commission (herein called the "Commission"), which shall be composed of the Secretary of Commerce (or his designee), and four members from private life to be appointed by the President by and with the advice and consent of the Senate. Three members shall constitute a quorum of the Commission. The President shall designate one appointed member as chairman of the Commission.

(2) The term of office of each appointed member of the Commission shall be five years, except that the terms of office of the members first taking office shall expire, as designated by the President at the time of appointment, one at the end

of two years, one at the end of three years, one at the end of four years, and one at the end of five years after the date of enactment of this Act; and any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed shall be appointed for the remainder of such term. Any appointed member of the Commission may be removed by the President for inefficiency, neglect of duty, or malfeasance in office. Each appointed member, except the chairman, shall receive compensation at the rate of $15,000 per annum; and the chairman shall receive compensation at the rate of $17,500 per annum; but any member who is an officer of the Government shall receive no compensation in addition to that received by him as such officer. No member of the Commission shall engage in any other business, vocation, or employment than that of serving as a member of the Commission, except in the case of members who are officers of the Government.

(3) The principal office of the Commission shall be in the District of Columbia, but the Commission or any duly authorized representative may exercise any or all of its powers in any place. The Commission shall hold such meetings, conduct such hearings, and receive such reports as may be necessary to enable it to carry out the provisions of this Act.

(4) There are hereby established within the Commission—

(A) a General Manager, who shall discharge such of the administrative and executive functions of the Commission as the Commission may direct. The General Manager shall be appointed by the Commission, shall serve at the pleasure of the Commission, shall be removable by the Commission, and shall receive compensation at a rate fixed in the Commission's discretion but not to exceed $15,000 per year; and

(B) a Division of Research, a Division of Military Application, and a Division of Civilian Application, but the Commission may from time to time create such additional divisions as it deems necessary. Each division shall be under the direction of a Director who shall be appointed by the Commission and shall receive compensation at a rate of $12,000 per annum. The Director of the Division of Military Application shall be a member of the Armed Forces. The Commission shall require each such division to exercise such of the Commission's powers under this Act as the Commission may determine, except that the authority granted under section 4 (a) of this Act shall not be exercised by the Division of Research.

(b) GENERAL ADVISORY COMMITTEE.—There shall be a General Advisory Committee to advise the Commission on scientific and technical matters relating to operations, experimentation, and research and development, to be composed of nine members, who shall be appointed from civilian life by the President. Each member shall hold office for a term of six years, except that (1) any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed, shall be appointed for the remainder of such term; and (2) the terms of office of the members first taking office after the date of the enactment of this Act shall expire, as designated by the President at the time of appointment, three at the end of two years, three at the end of four years, and three at the end of six years, after the date of the enactment of this Act. The committee shall designate one of its own members as Chairman. The committee shall meet at least four times in every calendar year. The members of the committee shall receive a per diem compensation of $50 for each day spent in meeting or conferences, and all members shall receive their necessary traveling and other expenses while engaged in the work of the committee.

(c) MILITARY LIAISON COMMITTEE.—There shall be a Military Liaison Committee consisting of a chairman, who shall be the head thereof, and of a representative or representatives of the Departments of the Army, Navy, and Air Force, detailed or assigned thereto, without additional compensation, in such number as the Secretary of Defense may determine. Representatives from each of the three Departments shall be designated by the respective Secretaries of the Army, Navy, and Air Force. The committee chairman shall be appointed by the President, by and with the advice and consent of the Senate, and shall receive compensation at a rate prescribed by law for the Chairman of the Munitions Board. The Commission shall advise and consult with the committee on all weather modification and control matters which the committee deems to relate to military applications, including the control of information relating to the utilization thereof in military operations. The Commission shall keep the committee fully informed of all such matters before it and the committee shall keep the Commission fully informed of all weather modification and control activities of the Department of Defense. The committee shall have authority to make

written recommendations to the commission on matters relating to military applications from time to time as it may deem appropriate. If the committee at any time concludes that any action, proposed action, or failure to act of the commission on such matters is adverse to the responsibilities of the Department of Defense, derived from the Constitution, laws, and treaties, the committee may refer such action, proposed action, or failure to act to the Secretary of Defense. If the Secretary concurs, he may refer the matter to the President, whose decision shall be final.

(d) APPOINTMENT OF ARMY, NAVY, AND AIR FORCE OFFICERS.—Notwithstanding the provisions of section 1222 of the Revised Statutes (U. S. C., title 10, sec. 576), section 212 of the Act entitled "An Act making appropriations for the Legislative Branch of the Government for the fiscal year ending June 30, 1933, and for other purposes", approved June 30, 1932, as amended (U. S. C., title 5, sec. 59a), section 2 of the Act entitled "An Act making appropriations for the legislative, executive, and judicial expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety-five, and for other purposes", approved July 31, 1894, as amended (U. S. C., title 5, sec. 62), or any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Director of the Division of Military Application established by subsection (a) (4) (B) of this section, without prejudice to his commissioned status as such officer. Any such officer serving as Director of the Division of Military Application shall receive, in addition to his pay from the United States as such officer, an amount equal to the difference between such pay and the compensation prescribed in subsection (a) (4) (B) of this section. Likewise, notwithstanding the provisions of any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Chairman of the Military Liaison Committee established by subsection (c) of this section, without prejudice to his commissioned status as such officer. Any such officer serving as Chairman of the Military Liaison Committee shall receive, in addition to his pay from the United States as such officer, an amount equal to the difference between such pay and the compensation prescribed in subsection (c) of this section.

(e) INTERDEPARTMENTAL ADVISORY BOARD.—In order to promote cooperation and coordination between governmental agencies concerned with weather modification and control, there is hereby created an interdepartmental advisory board to the Commission, to consist of the Secretary of Agriculture, the Secretary of the Interior, the Secretary of State, or their designated representatives, and representatives of such other governmental agencies as the President may designate. It shall be the function of the Board to meet with the Commission from time to time, at its request, and to advise the Commission with respect to matters relating to weather modification or control in which their agencies, or any other agencies of the Government, may be interested.

RESEARCH AND OPERATIONS

SEC. 4. (a) RESEARCH.—The Commission is directed to exercise its powers in such manner as to insure the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. To this end the Commission is authorized and directed to conduct, and to make arrangements (including contracts, agreements, and loans) for the conduct of, research and development activities relating to—

(1) the theory and development of methods of weather modification and control, including processes, materials, and devices related thereto;

(2) utilization of weather modification and control for agricultural, industrial, commercial, military, and other purposes; and

(3) the protection of life and property during research and operational activities.

(b) To the end that methods of weather modification and control may be applied with the greatest benefit to the public interest and national security, the Commission is authorized and directed to conduct, and to make arrangements (including contracts, agreements, and loans) for the conduct of, operations and projects for weather modification and control.

(c) The Commission may make arrangements as provided in subsections (a) and (b) without regard to the provisions of section 3709 of the Revised Statutes (U. S. C. title 41, sec. 5) upon certification by the Commission that such action is necessary in the interest of the common defense and security, or upon a showing that advertising is not reasonably practicable, and may make partial and advance

payments under such arrangements, and may make available for use in connection therewith such of its equipment and facilities as it may deem desirable. Such arrangements shall contain such provisions to minimize danger to life or property, and to require the reporting and to permit the inspection of work performed thereunder, as the Commission may determine: but shall not contain any provisions or conditions which prevent the dissemination of scientific or technical information, except to the extent such dissemination is prohibited by law.

MILITARY APPLICATIONS OF WEATHER MODIFICATION AND CONTROL

SEC. 5. The Commission is authorized to conduct experiments and do research and development work in the military application of weather modification and control. The President, from time to time, may direct the Commission to authorize the armed forces to engage in activities for weather modification and control as a military operation.

MEASURES FOR WEATHER MODIFICATION AND CONTROL

SEC. 6. (a) LICENSES REQUIRED. It shall be unlawful, except as provided in section 5, for any person to engage in activities for weather modification and control except under and in accordance with a license issued by the Commission authorizing such action. Licenses shall be issued by the Commission only if, after considering the effects of the action authorized thereby upon the equitable distribution of precipitation among the States, the interests of agriculture, industry, commerce, the general welfare, and the common defense and such other factors as it may deem relevant, the Commission determines that the issuance of such licenses will be in the public interest.

(b) ISSUANCE OF LICENSES.—The Commission shall issue licenses in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this Act. Each such license shall be issued for a specified period, shall be revocable at any time by the Commission in accordance with such procedures as the Commission may establish, and may be renewed on the expiration of such period. Where activities under any license might serve to maintain or to foster the growth of monopoly, restraint of trade, unlawful compensation, or other trade position inimical to the entry of new, freely competitive enterprises in the field, the Commission is authorized and directed to refuse to issue such license or to establish such conditions to prevent these results as the Commission, in consultation with the Attorney General, may determine. The Commission shall report promptly to the Attorney General any information it may have with respect to measures for the modification or control of weather which appear to have these results. No license may be issued to any person for activities which are not under or within the jurisdiction of the United States, to any foreign government, or to any person within the United States if, in the opinion of the Commission, the issuance of a license to such person would be inimical to the common defense and security.

(c) REGULATION OF RATES.—The Commission may, in connection with the issuance of any license, provide for the regulation of rates, fees, and charges which may be exacted for carrying out weather modification and control projects on a commercial basis.

(d) EXEMPTIONS FROM LICENSING REQUIREMENTS.—The Commission shall, to the extent it deems practical, by regulation provide for exempting from the licensing requirements laboratory research and experiments, activities of an emergent character for protection against frost, ice, or fog, and activities normally engaged in for purposes other than those of causing, increasing, or decreasing precipitation.

(e) INSPECTIONS, RECORDS, AND REPORTS.—The Commission is authorized by regulation or order to require such reports and the keeping of such records with respect to, and to provide for such inspections of, activities and studies of types specified in section 4 and of activities under licenses issued pursuant to this section as may be necessary to effectuate the purposes of this Act.

(f) This section shall take effect thirty days after the date of enactment of this Act.

INTERNATIONAL ARRANGEMENTS

SEC. 7. (a) DEFINITION.—As used in this Act, the term "international arrangement" shall mean any treaty approved by the Senate or international agreement hereafter approved by the Congress, during the time such treaty or agreement is in full force and effect.

(b) EFFECT OF INTERNATIONAL ARRANGEMENTS.—Any provision of this Act or any action of the Commission to the extent that it conflicts with the provisions of any international arrangement made after the date of enactment of this Act shall be deemed to be of no further force or effect.

(c) POLICIES CONTAINED IN INTERNATIONAL ARRANGEMENTS.—In the performance of its functions under this Act, the Commission shall give maximum effect to the policies contained in any such international arrangement.

GENERAL AUTHORITY

SEC. 8. (a) ADMINISTRATIVE FUNCTIONS.—In the performance of its functions the Commission is authorized to—

(1) establish advisory boards to advise with and make recommendations to the Commission on legislation, policies, administration, research, and other matters;

(2) establish by regulation or order such standards and instructions to govern the carrying out of research or projects in weather modification and control as the Commission may deem necessary or desirable to minimize danger to life or property;

(3) make such studies and investigations, obtain such information, and hold such hearings as the Commission may deem necessary or proper to assist it in exercising any authority provided in this Act, or in the administration or enforcement of this Act, or any regulations or orders issued thereunder. For such purposes the Commission is authorized to administer oaths and affirmations, and by subpena to require any person to appear and testify, or to appear and produce documents, or both, at any designated place. No person shall be excused from complying with any requirements under this paragraph because of his privilege against self-inerimination, but the immunity provisions of the Compulsory Testimony Act of February 11, 1893 (U. S. C., title 49, sec. 46), shall apply with respect to any individual who specifically claims such privilege. Witnesses subpenaed under this subsection shall be paid the same fees and mileage as are paid witnesses in the district courts of the United States:

(4) appoint and fix the compensation of such officers and employees as may be necessary to carry out the functions of the Commission. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1949, as amended, except that to the extent the Commission deems such action necessary to the discharge of its responsibilities, personnel may be employed and their compensation fixed without regard to such laws. The Commission shall make adequate provision for administrative review of any determination to dismiss any employee;

(5) acquire such materials, property, equipment, and facilities, establish or construct such buildings and facilities, and modify such buildings and facilities from time to time as it may deem necessary, and construct, acquire, provide, or arrange for such facilities and services (at project sites where such facilities and services are not available) for the housing, health, safety, welfare, and recreation of personnel employed by the Commission as it may deem necessary;

(6) with the consent of the agency concerned, utilize or employ the services or personnel of any Government agency or any State or local government, or voluntary or uncompensated personnel, to perform such functions on its behalf as may appear desirable; and

(7) acquire, purchase, lease, and hold real and personal property as agent of and on behalf of the United States and to sell, lease, grant, and dispose of such real and personal property.

(b) SECURITY.—The President may, in advance, exempt any specific action of the Commission in a particular matter from the provisions of law relating to contracts whenever he determines that such action is essential in the interest of the common defense and security.

(c) ADVISORY COMMITTEES.—Service or employment of any person as a member of the General Advisory Committee established pursuant to section 3 (b) or as a member of any advisory board established pursuant to subsection (a) (1) of this section shall not be considered as service or employment bringing such person within the provisions of section 281, 283, 284, or 1914 of title 18 of the United States Code, or of any other Federal law imposing restrictions, requirements, or penalties in relation to the employment of persons, the performance of services, or the payment or receipt of compensation in connection with any claim, proceed-

ing, or matter involving the United States, except insofar as such sections may prohibit any such member from receiving compensation in respect of any particular matter which directly involves the Commission or in which the Commission is directly interested.

ENFORCEMENT

SEC. 9. (a) PENALTIES.—Whoever willfully violates, attempts to violate, or conspires to violate, any provision of this Act, or of any regulation or order prescribed or issued under section 6 (d) or 8 (a) (2), shall, upon conviction thereof, be punished by a fine of not more than $5,000 or by imprisonment for not more than two years, or both, except that whoever commits such an offense with intent to injure the United States or with intent to secure an advantage to any foreign nation shall, upon conviction thereof, be punished by a fine of not more than $20,000 or by imprisonment for not more than twenty years, or both.

(b) INJUNCTIONS.—Whenever in the judgment of the Commission any person has engaged or is about to engage in any acts or practices which constitute or will constitute a violation of any provision of this Act, or any regulation or order issued thereunder, it may make application to the appropriate court for an order enjoining such acts or practices, or for an order enforcing compliance with such provision, and upon a showing by the Commission that such person has engaged or is about to engage in any such acts or practices a permanent or temporary injunction, restraining order, or other order may be granted.

(c) SUBPENAS.—In case of failure or refusal to obey a subpena served upon any person pursuant to section 8 (a) (3), the district court for any district in which such person is found or resides or transacts business, upon application by the Commission, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both, in accordance with the subpena; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

GOVERNMENT ASSUMPTION OF LIABILITY

SEC. 10. With the approval of the Commission, any contract with a Government agency relating to weather modification or control may provide that the Government will assume and will become solely responsible for either or both of the following, to the extent that they arise out of the performance of said contract, are not compensated by insurance or otherwise, and do not result from a willful violation on the part of the contractor of any regulation or order established by the Commission pursuant to section 8 (a) (2)—

(1) all liability on account of claims by third persons, including employees of the contractor, for death, bodily injury, or loss of or damage to property, whether due to the negligence of the contractor or otherwise; but any contract so providing shall also contain appropriate provisions for notice to the Government of any claims made against the contractor, with respect to any alleged liability for death, bodily injury, or loss of or damage to property; and

(2) loss of or damage to property of the contractor arising as a result of a risk defined in the contract as unusual.

If such a provision is included in the contract, no cause of action with respect to any such claims may be maintained against the contractor but such third person's sole cause of action and only remedy shall be by suit against the United States in the Court of Claims for the recovery of his reasonable and entire compensation with respect to such claims; but this section shall not create a cause of action in favor of any person against the United States unless, except for this section, a cause of action would lie against the contractor. In any such suit the United States may avail itself of any and all defenses, general or special, that might be pleaded by the contractor were the contractor the defendant in the suit.

REPORTS

SEC. 11. The Commission shall submit to the Congress, in January and July of each year, a report concerning the activities of the Commission. The Commission shall include in such report, and shall at such other times as it deems desirable submit to the Congress, such recommendations for additional legislation as the Commission deems necessary or desirable.

DEFINITIONS

SEC. 12. As used in this Act—

(a) "Weather modification and control" means initiating, changing, or controlling the courses or effects of the forces, masses, and other factors constituting weather phenomena, including temperature, wind direction and velocity, and the inducing, increasing, decreasing, and preventing, by artificial methods, of precipitation in the form of rain, snow, hail, sleet, or mist.

(b) The term "Government agency" means any executive department, commission, independent establishment, corporation wholly or partly owned by the United States which is an instrumentality of the United States, board, bureau, division, service, office, officer, authority, administration, or other establishment, in the executive branch of the Government.

(c) The term "person" means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, the United States or any agency thereof, any government other than the United States, any political subdivision of any such government, and any legal successor, representative, agent, or agency of the foregoing, or other entity, but shall not include the Commission or officers or employees of the Commission in the exercise of duly authorized functions.

(d) The term "United States", when used in a geographical sense, includes all Territories and possessions of the United States and the Canal Zone.

(e) The term "research and development" means theoretical analysis, exploration, and experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes.

APPROPRIATIONS

SEC. 13. There are hereby authorized to be appropriated such sums as may be necessary and appropriate to carry out the provisions and purposes of this Act.

SEPARABILITY OF PROVISIONS

SEC. 14. If any provision of this Act, or the application of such provision to any person or circumstances, is held invalid, the remainder of this Act or the application of such provision to persons or circumstances other than those as to which it is held invalid, shall not be affected thereby.

[S. 798, 82d Cond., 1st sess.]

A BILL To authorize the Secretary of Agriculture to conduct research and experiments with respect to methods of controlling and producing precipitation in moisture-deficient areas.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of Agriculture, acting through the Soil Conservation Service and Forest Service, shall conduct such research and experiments and shall take such further action as may be necessary to perfect at the earliest possible date methods of causing rain to fall in deficient areas to provide supplemental moisture for production of crops and grasses, prevention of forest fires, protection of municipal water supplies, and other purposes.

SEC. 2. (a) The Department of Commerce and other Federal agencies possessing meteorological and other records and data pertinent to the accomplishment of the purposes of this Act shall make such records and data available to the Secretary of Agriculture.

(b) Any excess Government property and equipment which the Secretary of Agriculture finds suitable for use and necessary in accomplishing the purposes of this Act shall be transferred to the Secretary of Agriculture without compensation therefor.

SEC. 3. There is authorized to be appropriated to the Department of Agriculture, from any funds in the Treasury not otherwise appropriated, such sums as the Congress may from time to time deem necessary to carry out the provisions of this Act.

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Senator ANDERSON. We will deal with them concurrently. We will not take up one bill at a time. In other words, a witness can testify on sections of all three bills that are common, or if there is a particular bit of testimony that relates to a specific bill, he can so identify it.

For example, tomorrow morning Secretary Chapman will be here and I imagine he will testify rather largely on that portion of Senate bill 5, the O'Mahoney bill, which relates to the research and demonstration of means of making sea waters into water which may be suitable for irrigation. That problem concerns not only an area like California but it also concerns certain of the Rocky Mountain States and other States where it is desirable to control salinity in the water used for irrigation. However, there is in Senate bill 5 a section which deals with the attempts to control weather and make rain. Therefore that is a part of the subject.

Senate bill 222 is one which is devoted entirely to the development and regulation of methods of weather modification and control, and suggests the establishment of a group which might participate in that work.

The bill by Senator Case, S. 798, is based, I am sure, on his own practical experience with rain making in western South Dakota and suggests the desirability of the Secretary of Agriculture conducting research through the Forest Service and through the Soil Conservation Service and to making reports at the earliest possible date.

It would have been desirable, perhaps, to have had all testimony from Government groups at the same time, but that may not ever be possible, and certainly is not possible in this instance. We will start with testimony from Mr. McDonald, the Assistant Chief of the Weather Bureau, and then testimony by three representatives from the General Electric Co., which has conducted the Project Cirrus and various other cooperative endeavors with the Army and Navy. Then tomorrow, Oscar Chapman, the Secretary of the Interior, will testify, as will Mr. Warne, the Assistant Secretary of the Interior, Michael Straus, the Commissioner of the Bureau of Reclamation, and Mr. Bennett, Assistant Director of Project Planning of the Bureau of Reclamation. In other words, we will give a full opportunity for that Government agency to be heard. I will ask Mr. Astin to state other witnesses to follow. Do you wish to identify those persons to follow?

Mr. ASTIN. Mr. Chairman, acceptances of the invitations to attend these hearings are still coming in. In addition to the representatives from the Department of the Interior, tomorrow, it is our understanding that Congressman McKinnon and Congressman Phillips of California will be heard. We have heard from Dr. Howell of Harvard, and I have the telegram that you sent to Mr. McKinney of New Mexico. Those would be witnesses for tomorrow.

On Friday we are expecting Dr. Vannevar Bush of the Carnegie Institution, Dr. Houghton of MIT, and Mr. Henry T. Harrison of the Weather Service, United Air Lines.

In accordance with your plan to go into the salt water extraction processes, we have lined up for Monday Mr. Davies of the Industrial Processes Co. of Philadelphia, Dr. Krick from Pasadena, Calif.—he will appear Monday afternoon—Dr. Sherwood of MIT, Mr. Holser of Pennsylvania State College, and Mr. Fox.

Senator CORDON. Do I understand that the plan is, on Monday, to limit the hearings to the matter of extraction of salinity?

Senator ANDERSON. No. As a matter of fact, Dr. Krick is head of one of the largest, possibly the largest of the rain-making organizations. He is moving from Pasadena to Denver, and found it impossible to be here this week. He asked to testify Monday morning. Subsequently he wired and asked if we could hear him Monday afternoon. He could not get here Monday morning. We will try to arrange the Monday afternoon schedule for his convenience.

May I say that if witnesses will help by the preparation of papers, it will be of assistance to us, and I know it will be of assistance to the press groups. I am sure some of this testimony gets a little complicated and I am quite confident the press would appreciate having it written insofar as possible.

In addition to the witnesses scheduled here, we do want to hear people who have had practical experience and who desire to make statements on this subject, which seems to hold quite a little promise for many parts of the world.

I may say in passing that temperatures have been surely rising the last few years. A study prepared by the Smithsonian Institution shows that temperatures are becoming higher throughout this continent, and particularly out through the Rocky Mountain areas where irrigation is usually practiced, and that rainfall is becoming somewhat lower gradually. We have seen some extremely large installations for hydroelectric power uselessly standing because no water has come to them. We have other areas where it is proposed to spend huge sums of money for irrigation development, and we naturally face the possibility that if one series of projects can dry up after a few years, others might also suffer.

Maybe there is a way of correcting some of it by the control of weather. I know that the trip which I made to the General Electric laboratories to study their processes and to see their results have persuaded me that if we could engage in a scientifically controlled experiment across most of the western part of the United States and perhaps all of the United States, with stations that might be on or off the continent of North America, that we could at least reach a determination as to how much promise there is in the theory of weather control.

I do not wish to say that I believe it is possible to control weather. I do not think any of us want to make that blunt statement, but I do think we are convinced that there is sufficient evidence that we ought to start paying some attention to it. It has some other implications that relate to our military activities, and these we hope to cover at a later date.

Senator Hunt, did you desire to make any statement?

Senator HUNT. No statement, except I hope we do not make a liar out of Mark Twain.

Senator ANDERSON. Well, up to his time nothing had been done. I think that a good deal of the effective work has been done since the death of Mark Twain.

All right, Mr. McDonald, with that introduction we will be very happy to hear from you, representing the Weather Bureau. I know Dr. Reichelderfer would have been happy to be with us, but the State Department pressed him into other duties. We are very happy to have you here, Mr. McDonald.

STATEMENT OF W. F. McDONALD, ASSISTANT CHIEF OF THE UNITED STATES WEATHER BUREAU, WASHINGTON, D. C.; ACCOMPANIED BY F. W. HALL, SPECIAL ASSISTANT, SCIENTIFIC SERVICES DIVISION, AND R. C. GRUBB, BUDGET OFFICER

Mr. McDONALD. Thank you, Mr. Chairman. I have a prepared statement which, with your permission, I would like to follow exactly and read into the record.

The proposal for extraction of fresh water from saline sources falls outside the province of Weather Bureau activity, hence the following remarks are directed solely to the proposals regarding artificial weather modification contained in the three bills, S. 5, S. 222, and S. 798 here under consideration. The Bureau has been deeply interested in, and has done considerable experimental work in cloud seeding and in the evaluation of results. We have had access to much of the data on scientific tests made by others in this country and by the weather services of other countries.

The Weather Bureau finds reasonable evidence that some cloud modification is possible, and we admit the possibility that rainfall may be locally influenced in some degree by artificial means. Most competent meteorologists concur in this opinion. The Bureau feels that it is still too early to try to define what can or cannot be done in this field and that a good deal more work is necessary before sound conclusions can be formed.

Weather is now controlled within enclosed spaces where heating, cooling, humidity, and air-current regulation can be obtained by design and choice. In the open air there is far less choice but nevertheless practically effective and somewhat controlled artificial weather modification is obtained through such means as orchard heating, flooding cranberry bogs, planting windbreaks, and there has even been some success, though costly, with the dispersal of fog on an extremely limited scale.

We are now seriously confronted with the question as to whether and how we can artificially induce and practically control the processes of natural precipitation. This problem, attacked even in the most localized sense, obviously faces vastly greater difficulties than those attending local temperature modification and fog dispersal.

First of all, natural precipitation occurs at any given place within a wide range of intensity and frequency. Moreover, the occurrence of natural precipitation often involves the reaction of air currents coming together from different sources, these sources usually widely separated in space. Notwithstanding all the intensive study these problems have received because of their relation to weather prediction, great gaps in knowledge still exist.

For example, we are constantly furthering our knowledge of the previous trajectories of those parcels of air that hold the moisture and produce the rainfall. We are studying the reasons why similar amounts of humid air arriving over a given place can produce very dissimilar amounts of rainfall or none at all. We are intensively seeking the explanation of the transformation from invisible moisture through clouds that sometimes consist of water droplets, at other times ice crystals, and are sometimes mixed, to the final stage where precipitation reaches the ground. Our knowledge of the varieties or

importance of natural particles resembling artificial nucleation agents or whether they are absolutely necessary to produce natural precipitation must be broadened.

We do know that there are no hedgerows to define boundaries or streets to guide traffic in the free atmosphere. Hence, we cannot set up experiments in rain making with definite limits in space, and controlled action in time.

The problems of air motion and cloud formation have engaged the attention of the leading meteorologists for decades. We have made good advances but do not have the final answers. The problem of precipitating clouds once formed will be partly won in the laboratory. It will be partly won by means of "flying laboratories." The Weather Bureau continues its researches concerning these matters although we have been handicapped by inability to obtain a suitable flying laboratory.

It is a basic scientific principle that evaluation of an effect produced by experimentation requires either complete controls on the conditions of the experiment—which is impossible in the atmosphere—or a predictable knowledge of the course the event takes when left alone without introduction of the artifice under investigation. Hence the evaluation of results under discussion is closely related to the Weather Bureau's work of weather forecasting, weather observing, and recording.

A scientific investigation of weather modification by artificial measures must involve the greatest possible knowledge of the processes that make weather. Research in weather forecasting and other fields in meteorology seeks exactly the same body of knowledge. We cannot conceive a profitable separation of research in rain making from the equally important and closely related field of general research in meteorology. With respect to research the Weather Bureau has kept in close touch with every development in the science, whether historical or as presently being pursued, by ourselves, by other agencies of the Government and by research institutions here in our own Nation, or by the weather scientists and physicists elsewhere in the world.

Meteorologists agree that there is posed at the outset for scientific rain-making research a most difficult problem of designing and testing repetitive experiments followed by top-notch statistical evaluation of carefully measured results to sort out long-run effects. In the Weather Bureau's tests of rain making we have diligently attempted to meet these conditions, and to avoid as far as possible the weak analogies, engaging half-truths and delusory conceptions that are so numerous in the weather business because the truth in weather science is so hard to get hold of, and the need to find and use it so great.

The whole matter is amongst the most serious problems attending man's age-long effort to adapt himself successfully to the natural world. Partly because the conquest of weather science is so beset with difficulty, but more, perhaps, because our civilization so urgently needs and seeks to reduce the hazards and losses from adverse weather factors, the problems of weather forecasting and weather control are peculiarly open to wishful thinking. This is not something new, but we have today an aggravated epidemic of the affliction, for we seem to be tuned to the expectation that any given technological miracle is purchasable at a price. We often fail to get what we pay for, and that

is especially true in so-called weather controls except on the most limited scale. But we can get more than we bargain for.

The latter is exemplified in the case of New York City's efforts to replenish a dangerously low water supply by the best artificial inducements available. Cooperation of the Weather Bureau was fully extended in the way of specialized forecasting service for the cloud-seeding operations then carried on. We have since been examining the results. So far we are unable to find any clear evidence that they got appreciable water beyond the amount unaided nature in due course provided. On the other hand, the city has reaped more than it bargained for in damage claims amounting at last report to something approaching $2,000,000, from citizens and communities that allege they were adversely affected by the acts of New York City in its efforts to increase the precipitation of the vicinity.

Senator ANDERSON. You would be a pretty good defense witness, then, against the damage suits.

Mr. MCDONALD. I would be an excellent defense witness.

Even the most enthusiastic proponents of the present feasibility of rain making on a practical scale claim no more than to be able to extract moisture from the air locally under conditions predisposing to the natural occurrence of rain or snow. Since these experimenters or "operators" only seek results under marginal conditions, or try to increase precipitation after it has started, the proof or disproof of their claims to success becomes doubly difficult and often impossible.

Moreover, we are confronted at all times by natural tendencies for precipitation to occur in excessive or abnormal amount with consequent damage to a wide variety of interests. This being the case, our inability to distinguish natural from induced effects opens the way to unlimited controversy including damage claims of the most difficult and extensive sort. Here is a new frontier of jurisprudence which may justify legislative action to clear the air.

There may be some need for legislation resembling the regulatory features of S. 222. If so, we would suggest consideration of more modestly designed and less restrictive legislation, to establish a relatively simple and economical regulatory procedure providing that specified large-scale activities undertaken in the release of agents or materials designed to influence or modify the occurrence of natural precipitation be suitably controlled and reported to the national authority.

We strongly represent the need for much greater emphasis on the search for knowledge of the whole meteorological substratum of the rain-making process in relation to those great natural controls on the weather we experience. Added resources for such accelerated researches must, however, be provided, especially to implement more fully the experimental process as a tool of weather research. The Bureau invites and encourages coordinated effort, and welcomes the serious weather researches of any scientist or any group that can find means—meaning finances—to do things that we have been unable to do.

However, we are of the opinion that research in meteorology should be guided all the way by reference to the best know-how in the general field of our science. In the broad sense this know-how exists within the Weather Bureau and in its coordinated relationships with other agencies and institutions, maintained under the basic legislation

running to the Department of Commerce. The Weather Bureau is charged by law to cooperate with other recognized agencies of research, including those of other countries, to "coordinate meteorological requirements," and to make results broadly available and practically useful in the national interest.

In our judgment the further scattering of Federal authority for meteorological research is a poor means of getting forward with the problems under discussion. And since any practical advance involves filling great gaps in our basic knowledge of the weather sciences, the most important question underlying the weather research objective of all three of these bills under consideration is the question of how best to get forward with such researches.

We are of the opinion that the Weather Bureau should continue to be responsible for leadership in this field. We doubt that a concentration of authority in a new Federal Commission, with complicated organs for action and advice, as proposed in S. 222, offers the most productive way toward progress in the science of meteorology, taken as a whole. Such a Commission would add tremendously to overhead costs, to say the least.

The Weather Bureau operates with a sober sense of responsibility to the public, and in respect to this important question of weather modification the Bureau has endeavored in an economical manner to do three things: First, to test methods of making rain artificially; second, to evaluate objectively the results of our own tests and the tests made by others; and, third, to accelerate investigations of cloud physics and natural rain processes in order to be in a better position to design and evaluate experiments in this field, and to improve our ability to forecast the weather.

In connection with the long-established and well-understood place of responsibility to the public held by the Weather Bureau as the constituted national weather service, we have the opinion that, apart from the possible need for some regulatory legislation, there now exists abundant authority to pursue the researches to which the proposed bills are directed. A new legislative pronouncement will be likely to divide and confuse the public understanding of Government responsibility in this field. Moreover, should such further division of national interest in meteorological research be established the costs to the taxpayer will be increased unnecessarily through duplication of work and diffusion of effort.

We invite the interest and energy behind these divisory proposals to concentrate cooperatively and constructively behind the Department of Commerce, where the national weather service is now established with broad legislative authority to do all things necessary to get forward with the national interest in the field of meteorology. In that case everything possible of achievement in these matters can be obtained and put to constructive use, at minimum cost to the taxpayers.

Senator ANDERSON. Mr. McDonald, I noticed here on page 4 that you say that you "cannot conceive a profitable separation of research in rain making from the equally important and closely related field of general research in meteorology."

I assume from that that you would be against the proposal in Senator Case's bill, for example, to turn this over to the Department of Agriculture?

Mr. McDONALD. I think we would be for the general reasons that I have tried to set forth.

Senator ANDERSON. You would be equally against the proposal in my bill that we set up some sort of a general group, of which the Department's Weather Bureau is one?

Mr. McDONALD. Correct.

Senator ANDERSON. You say here that "We are of the opinion that the Weather Bureau should continue to be responsible for leadership in this field." How much has been done in the knowledge of rain making by the Weather Bureau? I am just trying to find out whether you have leadership or whether the private rain makers in General Electric have leadership.

Mr. McDONALD. They have leadership in advertising.

Senator ANDERSON. Did anyone else work out the idea that it was possible artificially to produce storms?

Mr. McDONALD. That idea has been broached in one form or another historically over a long period of time. This is not the first effort.

Senator ANDERSON. There was a man who advocated doing it by gunpowder.

Mr. McDONALD. Yes.

Senator ANDERSON. But advocating doing it by the development of silver iodide treatment—was that worked out by the Weather Bureau?

Mr. McDONALD. No. We give full credit to the experiments done with silver iodide.

Senator ANDERSON. Who has leadership, that is what I am trying to find out? Who does have leadership in the field?

Mr. McDONALD. Are we talking about leadership in advertising or leadership in science?

Senator ANDERSON. Do you think that silver iodide has contributed anything to this?

Mr. McDONALD. Yes.

Senator ANDERSON. Did it come from the Weather Bureau?

Mr. McDONALD. I do not know. The Weather Bureau did not originate it.

Senator ANDERSON. The Weather Bureau discourages it; does it not?

Mr. McDONALD. I do not think we do; no.

Senator ANDERSON. You do not?

Mr. McDONALD. I do not think our position on the silver iodide experimentation is one of discouragement. We have tried to test results.

Senator ANDERSON. Let me go a step further. You say on page 8 of your statement:

> The Weather Bureau operates with a sober sense of responsibility to the public, and in respect to this important question of weather modification the Bureau has endeavored in an economical manner to test methods of making rain artificially.

Mr. McDONALD. That is right.

Senator ANDERSON. You are familiar with the fact that Dr. Krick's organization is operating in Oregon?

Mr. McDONALD. Yes.

Senator ANDERSON. And that in Oregon College they are testing his results. Are you familiar with what tests they have made?

Mr. McDONALD. Not precisely. Perhaps Mr. Hall is.

Senator ANDERSON. Wait a minute, I am trying to find out. Are you following the tests in Oregon?

Mr. HALL. Yes.

Mr. McDONALD. Pardon me, Senator, but the specialist on this matter, Mr. Hall, who is here with me——

Senator ANDERSON. May we have his name for the record?

Mr. McDONALD. The recorder has his name, I am sure. Mr. Hall will perhaps have to answer some of these questions.

Senator ANDERSON. I am sure the recorder has his name, but is there an objection to those of us on the committee having his name?

Mr. McDONALD. None whatsoever. You mean Mr. Hall's name?

Senator ANDERSON. May we have it?

Mr. McDONALD. Mr. F. W. Hall, special assistant in the Scientific Services Division of the Weather Bureau, with a full-time responsibility to work in this area of evaluation of these results. Now, may I ask your indulgence, Mr. Chairman, to go back to the question you posed earlier: What has the Weather Bureau done?

Senator ANDERSON. You had money for some thunder cloud experiments; did you not?

Mr. McDONALD. I have a statement here that is not too long, two pages, which, if you wish, I will be very glad to read into the record.

Senator ANDERSON. I think we had better have it.

Mr. McDONALD. This summarizes very briefly what the Weather Bureau itself has done in this matter. As a result of laboratory experiments and indications that supercooled clouds of water droplets could be converted into clouds of ice particles by introduction of dry ice——

Senator ANDERSON. These are laboratory experiments whereby the Weather Bureau——

Mr. McDONALD. This describes general testing, general experimentation.

Senator ANDERSON. Who made these laboratory tests?

Mr. McDONALD. The General Electric tests began this.

Senator ANDERSON. I see.

Mr. McDONALD. Yes; we are giving full credit.

Senator ANDERSON. I was wondering about this leadership of yours. Go ahead.

Mr. McDONALD. May I go back to your point?

Senator ANDERSON. Yes.

Mr. McDONALD. What we mean to say, and perhaps did not say clearly enough in this statement, leadership in the general field of meteorology.

Senator ANDERSON. But you have consistently and steadily fought rain making.

Mr. McDONALD. No.

Senator ANDERSON. No?

Mr. McDONALD. No.

Senator ANDERSON. The Weather Bureau has taken steadily the position there is not anything in it up until this testimony; has it not?

Mr. McDONALD. Let me read into the record what we have done.

Senator ANDERSON. All right.

Mr. McDONALD. Affirmatively and in fact to get into this field of research.

Senator ANDERSON. Proceed.

Mr. MCDONALD. As a result of laboratory experiments made by General Electric, if you please, and also I may say of findings by meteorologists in Europe and their conclusions regarding the probable importance of ice crystals in the rain-making process, a finding which itself is still not conclusively proved as the only rain-making process—the basic finding on which this whole thing began is still open to some question as to how important it is, or at any rate as to whether it is always present in rain. Now, I take it that far back to show why we pick up this particular facet of it in these laboratory experiments, and I will, with your indulgence, read this into the record.

As a result of laboratory experiments and indications that supercooled clouds of water droplets could be converted into clouds of ice particles by the introduction of dry ice, the Weather Bureau, in a joint project with the United States Air Force and the National Advisory Committee for Aeronautics, began an extensive test program in January 1948, to—

> determine in definite quantitative terms the practical limits and general utility of cloud modification processes in producing or suppressing precipitation. * * *

The project was begun in Ohio where an extensive network of recording rain gages was available, and where radar facilities permitted observations of precipitation. At this location 38 seeding operations on stratus clouds, and 79 operations on cumulus clouds were carried out. The location was then shifted to the Donner Pass, Calif., area where 15 operations on orographic clouds were conducted. Finally, the project moved to the vicinity of Mobile, Ala., where 39 additional seedings were made, this phase of the project terminating in the middle of June 1949. In all, nearly 200 individual tests were conducted. Beginning in February 1949, and continuing to June of the same year, the Weather Bureau operated a ground silver iodide generator at Colfax, Calif., at the foot of the Donner Pass. This location was chosen as being perhaps the most favorable for the use of silver iodide. The generator was operated on a periodic basis and seeded and nonseeded periods were compared for the period of operation. No significant differences in precipitation could be detected.

Throughout the above periods, and continuing at the present time, the entire resources of the Physical Research Division of the Weather Bureau have been thrown into the problem of the mechanism of precipitation, with the expectation that by increasing our knowledge of the fundamental processes involved it will be possible to more definitely define the conditions in which artificial modification may be of practical importance. Extensive laboratory tests are under way in this field right now.

The Bureau examined the rainfall distributions in Arizona for October 1948, and also for the three summer months of 1948 and 1949, to evaluate the results of commercial seeding in the upper central portion of the State during these periods. No significant results were noted, the seeded area exceeding the remainder of the State in three of the months, and falling behind for the other 3 months.

The Bureau is at present analyzing the results of the seeding operations of the California Electric Power Co. at Bishop, Calif., which have been continuing since February 1948. This study is not quite completed. The Bureau is continuing its cooperation with the com-

pany on this project which, it is hoped, will be continued for as many years as necessary to obtain the answer.

The Weather Bureau is also analyzing the results of the rain-making operation of the city of New York over the Catskill Mountains during the past year.

Claims of commercial rain makers in the West are being examined, and analyses are being attempted where information permits.

I would like to say parenthetically, for the most part there are no controls. The information on which to test the matter is exceedingly difficult to get. They do not get observations in connection with their work at all. They leave it to somebody else to pick up the pieces.

The Weather Bureau stationed Mr. William Lewis with Project Cirrus of the General Electric Co. as its representative, and Mr. Lewis made important analyses of the results of that project.

At present the Bureau is analyzing the results of other Project Cirrus tests in cooperation with General Electric and the Signal Corps, sponsor of the project.

Senator ANDERSON. The second set that you list is one that you apparently refer to there:

to evaluate objectively the results of our own tests and the tests made by others.

Mr. MCDONALD. That is right.

Senator ANDERSON. May I return to this situation in Oregon, where Dr. Krick's organization is working with the Oregon State College, and they are evaluating and attempting to pass on what he is doing and making a basis for payments by the farmers to the rain makers. Are you familiar with the work?

Mr. MCDONALD. Mr. Hall would speak to that. He is the man who is following these tests and trying to evaluate results.

Senator ANDERSON. Are you evaluating those Oregon tests?

Mr. HALL. Sir, we are not evaluating them ourselves, although we are keeping in touch with it. When the evaluation began, a series of correspondence with the Weather Bureau was held and eventually one of the members of the Oregon State College visited our Bureau and discussed the methods for this analysis. Subsequently we have had further correspondence with Mr. R. T. Beaumont who is, I believe, in charge of the analysis there, with further regard to the methods of analysis.

We do have a copy of his final analysis and results, rather the pay scale, as you say—we have that on file. We have written again to Mr. Beaumont, offering further services of the Bureau in connection with the analysis. We have not heard any more from him for, I would say, about 2 months.

Senator ANDERSON. But the Bureau has not done any real evaluating itself. It is all done by Oregon State College?

Mr. HALL. That is right. We are trying to encourage the evaluation by others on a scientific basis, since our facilities do not permit us at the present time to evaluate all of these individual projects.

Senator ANDERSON. The ones you have evaluated, then, are the Bishop project of——

Mr. HALL. Yes, sir.

Senator ANDERSON. And the seeding projects of your own which went on under a — was that not a thunder cloud appropriation which you had? What did you do this work under? What was the appropriation?

Mr. McDONALD. Since you open that question, we, as a Bureau, have never had a direct and clear appropriation—I mean, an addition to our funds in terms of this experimental work.

We have had to cut it out of our general fund where we could get it, as we could get it, and I must say it is pitifully small for the importance of the project. We are the first to say that. We stand seriously handicapped, and I do not want to seem to impugn some other parts of Congress in saying this.

We are taxpayers, too, and we know that sales appeal in terms of appropriations is pretty important, but somehow or other we have not managed to get the money to get into this thing on the scale which we ourselves believe to be proper in the investigation of this matter.

Senator ANDERSON. The Government indirectly is paying huge sums for this. One organization has more than $100,000 worth of contracts with cattlemen in my State, and certainly that is all going to be charged to expense, and the Government is going to pay 40 to 50 percent of that—probably more than that.

Mr. McDONALD. I hope you will realize that we are just one little part of the Government and that I could get over the barrel so fast and so far if I open up here and speak as a private citizen and a taxpayer on this matter, until it would not be funny.

Senator ANDERSON. I think that would be helpful.

Mr. McDONALD. Well, I think the Government is wasting a lot of money in this field for the failure to get behind the agency that has the best know-how in the field. I defy anybody to bring to this matter a more serious and a greater interest. I defy anybody to bring to this matter a higher sense of public responsibility than the Weather Bureau brings to it.

Senator ANDERSON. But if you approach it with a preconceived notion that it is no good, the money that would be spent with you might be wasted. It would be like turning over the development of the atomic bomb to some group that says, "We will try it but we know it cannot be built."

Mr. McDONALD. Mr. Chairman, you certainly are putting words into our mouths, and I must protest that in some manner or other I think you have taken a judgment about the Weather Bureau and its position on this matter which—well, I hesitate to say it, but which does not just quite fairly take into account the whole position of the Bureau.

Senator ANDERSON. I admit that is possible. I recognize that fact, but after one has tried for months to put a bill together and has had one group steadily working in the other direction, one comes to conclusions if one is at all mentally alert——

Mr. McDONALD. Mr. Chairman, I would only suggest that you go back, if it is possible, to evaluate the two sides of this controversy. You seem to say the Weather Bureau stands alone in a conservative position, to put it mildly. I think you will find that meteorologists stand together on our side of this question wherever they are.

Senator CORDON. What is your side?

Mr. McDONALD. We are conservative about this. We think it is sufficiently important to warrant running down to the bottom, absolutely so, but we are not going to predict any miraculous results as we sit here today, and we do not think it is wise to advertise it as it has been advertised, at this stage of the game.

Senator CORDON. What do you think should be done that might be said to be a constructive field of criticism? What is your idea as to what should be done?

Mr. MCDONALD. Are you asking what would be our plan if we had an appropriation?

Senator CORDON. Yes.

Mr. MCDONALD. In brief it is this, and this is very brief. It can be spelled out at great length. This is one page.

The Weather Bureau envisions as further steps in tackling the over-all problem of weather modification and artificial precipitation, extensive field tests both in the air and on the ground, and comprehensive laboratory research.

A series of field tests and related studies will be conducted under different climatic and meteorological conditions in various parts of the country. Such a program can be expected to reduce the uncertainties as to quantitative results obtainable and to define the meteorological conditions favorable and unfavorable for artificial precipitation.

The laboratory work will be devoted to an examination of the basic processes producing clouds and precipitation. Those are physical processes, perhaps chemical, we do not know, perhaps electrical. These laboratory studies will assist us in determining the links in the chain of rainfall-producing mechanisms where human influence can be expected to be most effective in providing beneficial results.

This program will require additional technical staff and field equipment as well as greatly expanded laboratory facilities.

Senator ANDERSON. I am going to surprise you, Mr. McDonald, by saying that I would not object to having the Weather Bureau do that. I would like to see somebody do it and I wondered why the Weather Bureau, so far as I can find out, has never asked for 5 cents to do it. When did you ask for these appropriations for these extra laboratories?

Mr. MCDONALD. Mr. Grubb, the budget officer of the Bureau, Mr. R. C. Grubb. He has the figures in hand on that very question.

Senator ANDERSON. Can you furnish us a list of the requests that you have made from the Bureau of the Budget for funds to do this sort of thing year after year, construction of laboratories, testing out of this silver iodide theory, the testing out of when it is best to do these things? I know that you did get some money that you spent on this thunder cloud experiment, but when did you try the actual request for funds for rain making?

Mr. GRUBB. The first year, Mr. Chairman, was in 1949. We requested from the Bureau of the Budget——

Senator ANDERSON. This rain making had been going on for years by 1949. Private investors had spent fortunes trying to get this work done. You spoke of the work out in Arizona yourself in 1948. I think Mr. Searles is here to testify this morning. The first time you asked for it was in 1949?

Mr. GRUBB. That is for artificial precipitation. We asked for research funds, naturally, in previous years.

Senator ANDERSON. Yes; I understand that.

Mr. GRUBB. And some of our research funds were undoubtedly devoted to the initial steps.

Senator ANDERSON. But for this project, this work of testing rain making, it began in 1949. What did you ask for?

Mr. GRUBB. From the Bureau of the Budget $1,867,000 for a research program.

Senator CORDON. What year?

Mr. GRUBB. Fiscal year 1949.

Mr. MCDONALD. That was requested in 1947, then?

Mr. GRUBB. Yes; for fiscal year 1949.

Senator ANDERSON. Senator Case, do you have a question there?

Senator CASE. I was wondering, Mr. Chairman, if that was for a general research program, and how much of that was broken down for the particular thing we are discussing here.

Mr. GRUBB. This is for the general research program. The increase for the preceding year was approximately $1,200,000, which was principally for artificial precipitation. I will have to furnish for the record, Mr. Chairman, details as to each individual project.

(NOTE.—Mr. Grubb subsequently supplied the following information:)

Weather Bureau plans for investigating artificially induced precipitation were first developed during the winter of 1946–47 and first represented formally as a budget requirement to the Department of Commerce on July 1, 1947. The amount requested at that time for this program was $2,163,076. Subsequently, the following amounts were requested:

July 1, 1948	$1, 538, 014
July 1, 1949	2, 651, 124
July 1, 1950	2, 430, 231

Present plans call for representing a comparable amount on July 1, 1951.

Details of the original plan as finally represented in 1947 to the Bureau of the Budget as a budget requirement for fiscal year 1949 are quoted below:

"The investigation of artificially induced precipitation will be carried out by one of two major research groups to be organized under the project leader. This project will be conducted in three phases: (1) laboratory study, (2) study of cloud 'seeding' from the ground, and (3) study of cloud 'seeding' from aircraft. The laboratory experiments are designed to determine the important physical factors that control the precipitation of super-cooled droplets under very carefully controlled and measurable conditions. These data developed in the laboratory will be checked by a study of the results of 'seeding' clouds from the ground and from aircraft with the object of determining under what specific conditions precipitation can be produced and how much may be expected. A ground operation group will establish a network along the lee side of a sharp ridge at a suitable location; release of activators, such as dry ice particles or silver iodide, in cloud areas will be made throughout the network by means of balloons. The quantity of precipitation produced as a result of the 'seeding,' compared with the precipitation arising from natural meteorological factors will be checked. A study of distances between release points within the network will be made to determine the most effective spacing of artificial stimuli. The air operation group will work both in cooperation with the ground group and independently. The air group will be utilized primarily for 'seeding' operations in selected areas where meteorological conditions are favorable.

"A second major group will devote its attention to other projects in basic physical research. This work, principally laboratory, will consist of cold chamber investigation of cloud and ice particle formation and study of the electrical phenomena of precipitation. Results of laboratory developments will be checked with conditions observed in the natural state, and coordinated with the field studies described above."

The Weather Bureau's present plan, previously introduced in this record, is substantially the same as that originally represented.

Funds were included in the President's budget (fiscal year 1949) for the plan first developed in 1946–47 for consideration by Congress. This request was disallowed in its entirety. The Weather Bureau has, however, continued to represent this requirement to the Department and to the Bureau of the Budget each fiscal year, but no funds have been included in the President's Budget during the past 3 years for a program of this nature.

Senator ANDERSON. What I am trying to get to is this. Senator Case has been living out in an area that has become a little dry, and when they tried to get some rain making, he had to dig up his private money, along with that of other people, for rain making experiments; is that not correct?

Senator CASE. We did not put in a fortune.

Senator ANDERSON. You put in private money.

Senator CASE. We put in some private money.

Senator ANDERSON. And got, you think, some results?

Senator CASE. We thought we did.

Senator ANDERSON. Did the Weather Bureau evaluate those results?

Mr. MCDONALD. I presume not. I do not know whether that particular experiment came to our attention or not.

Mr. HALL. I do not recall that particular experiment.

Senator ANDERSON. Let me give you one thing that Dr. Krick refers to. He has a release No. 8. I am sorry I have no way of knowing when this was put out, but I assume it was early in 1951, from the Water Resources Development Corporation, and he talks about their target area and he lists a series of seven places in New Mexico and shows that their increase ranged from 419 percent down to 156 percent. Then he lists the areas outside the target area where he did not seed and they got 44 percent of normal up to 125, but nearly all of them were below normal. Have you evaluated that?

Mr. HALL. Yes, sir, we have.

Senator ANDERSON. What is your evaluation of that?

Mr. HALL. Our evaluation, as far as we can make it, shows that the seeded area got roughly 15 percent more than the surrounding areas, but that that state of affairs occurs roughly every 2 or 3 years naturally, and has done so in the past 40 years.

Senator CORDON. In the same area?

Mr. HALL. Yes, sir.

Senator ANDERSON. Therefore, you would feel that what these ranchers spent for rainmaking was probably wasted?

Mr. HALL. Sir, I do not know that on any one experiment like that we can make up our minds very much about what effect the silver iodide has because, you see, it always comes out in these uncertain terms of probabilities.

I think what we will have to do is just to keep analyzing many, many of these cases and finally build up a large fund of knowledge on them, and eventually we may narrow the probabilities down to such an extent that we can say something about the quantities that can be produced.

Senator ANDERSON. Mr. Hall, let me turn to one section of this statement by Mr. McDonald and get your comment on it, because I do know that you have tried to be very much interested in this sort of work [reading]:

> It is a basic scientific principle that evaluation of an effect produced by experimentation requires either complete controls on the conditions of the experiment—

and then something else. If I can take just that part about it, do you not feel that if anyone is to know what happens by the spraying of silver iodide into the atmosphere, there must be complete knowledge of what is going on across the entire country?

Mr. HALL. That would be very desirable, but as is mentioned there, it cannot be obtained in nature.

Senator ANDERSON. It cannot be obtained? You could not find out who is putting silver iodide into the air?

What I am trying to get at is this. As you know, there was an experiment going on for quite a while in which 50 pounds of silver iodide was put into the air in New Mexico, and rainfall got quite heavy in the eastern part of the country. Let us pray there is no relationship between the two, but when the amount was reduced to 20 pounds per week there was a dropping off of these storms in the East.

Again there may be no relationship between the two, but would it not be desirable when you were trying to study results in Ohio, to know how much silver iodide was being put into the air in Arizona or California or New Mexico?

Mr. HALL. Yes, sir, that is going to be quite a problem in the future with all these unregulated, and a lot of them unknown, experiments being conducted.

Senator ANDERSON. Exactly, unknown. Do you recognize that there is one rancher who owns three generators out in my part of the country?

Mr. HALL. Yes, we have heard a lot of reports to that effect.

Senator ANDERSON. What opportunity is there for a complete control on an experiment if you may be spraying silver iodide into the skies one place and this rancher just over the hill has three generators working?

Mr. HALL. It is going to be impossible.

Senator ANDERSON. I am trying to find out if you think there is any necessity, then, for a Federal bill which would keep track of what is going on.

Mr. MCDONALD. May I raise a point, which I think is very important to this line of discussion. The line of discussion is based, I believe, if I understand it correctly, on an acceptance of the silver iodide thesis pretty much as it has been proclaimed, with no questions about its efficacy.

Moreover, I believe that line of questioning fails to take account of a fact recently discovered at MIT or the Cambridge Laboratory of the Air Force. I am told by meteorologists in the Air Force who are doing extensive meteorological research work at Cambridge——

Senator ANDERSON. Dr. Houghton will be here tomorrow or the next day and we will hear him on the subject.

Mr. MCDONALD. I am told that they have discovered that there is a photosynthetic decay in this silver iodide effect, and that in full sunlight silver iodide loses much of its efficiency in 20 minutes. Now, it seems to me this whole discussion must stop to consider possibilities like that which have not been drawn into this thing so far.

Senator ANDERSON. I agree with that, but what do you do with a group of men who pay their money and get rainfall? How do you start saying to them that silver iodide passes off in 20 minutes? If rainfall comes, they are naturally going to continue to contribute.

I mean you are going to have some difficulty even with Senator Case who paid his money, and it paid off like a slot machine, like a good slot machine.

Senator WATKINS. You mean he hit the jackpot once.

Mr. McDONALD. Maybe it was like a slot machine. I think that is a very, very appropriate comparison.

Senator ANDERSON. I think it may be, but what I was trying to find out was——

Senator CASE. What the Senator meant was it hit the jackpot.

Senator ANDERSON. It did hit the jackpot. What I am trying to say is; is it possible for us to find out from you whether you believe there would be any value in knowing what these experiments are—to make judgments?

Mr. McDONALD. Senator, I cannot tell you too many times or too emphatically, we try to approach this problem without preconceptions and to establish a belief on the basis of facts and nothing else. It is as simple as that.

Senator CORDON. That raises a major question here: The extent to which you seek the facts. If you spray silver iodide into the air, that is a fact.

Mr. McDONALD. Yes.

Senator CORDON. It is released. If within a reasonable period of time rain falls, that is a fact.

Mr. McDONALD. Yes.

Senator CORDON. Now, whether the first fact has any relation to the second fact——

Mr. McDONALD. Is open to all kinds of questions.

Senator CORDON. Is a matter for conclusion, but if those two facts exist, whether they are connected or not connected, is a matter for investigation, is it not?

Mr. McDONALD. Yes; it is.

Senator CORDON. Then if we have a series of those facts over the United States, and if, as a result, although perhaps disconnected, in each instance there does follow precipitation, that should raise in a reasoning mind a question as to whether there is connection.

Mr. McDONALD. That is exactly our process of test.

Senator CORDON. It seems to me that Senator Anderson's position is not an assumption that the two are connected. It is an assumption that the fact that one result followed another action is enough to put the United States of America on inquiry and necessitate that sort of an organization which can take those facts in hand and correlate them over the United States, which then, I think, requires a conclusion that there must be an organization to do that. Is that sound?

Mr. McDONALD. Well, that is pretty involved.

Senator CORDON. I think it is fairly simple if you follow it through.

Senator ANDERSON. I just say that what you stated, Senator Cordon, is exactly the position I have taken. I do not claim that spraying silver iodide into the air produces rainfall, but I say if you spray it on Friday and it rains on Saturday, and you spray it on Friday and it rains on Saturday and you do that for 20 straight weeks, I begin to say to myself there might be some connection. The Weather Bureau says you can't prove it and therefore there is not any.

Mr. McDONALD. Senator, I think that line of connection is just as reasonable as to say because the washerwomen hang out their clothes generally on Monday and it rains on Wednesday, that there is a connection between those two things.

Senator CORDON. If that were true, you could.

Senator ANDERSON. That is exactly why I question the advisability of turning over any money to the Weather Bureau. You see where the trouble is.

I can see that if men spray silver iodide into the air and it subsequently rains, and then they do it again and it subsequently rains and that thing goes on and there is a periodicity to their spraying and periodicity to the resulting rainfall, I think there might be a connection. You say there is absolutely none?

Mr. MCDONALD. No; we do not argue against that whatsoever.

Senator ANDERSON. You just got through saying that it was just like hanging out the wash on Monday and it raining on Wednesday.

Mr. MCDONALD. As far as connection is concerned, it might be just as remote as that.

Senator ANDERSON. Then, that is an absolute statement on your part that the silver iodide has nothing to do with the rainfall?

Mr. MCDONALD. No, sir; that must not be considered so.

Senator ANDERSON. I beg your pardon, there was no connection between the woman doing the washing and the raining on Wednesday. Therefore, you are saying that there is nothing to the spraying of silver iodide into the air.

Mr. MCDONALD. May I tell you a story?

Senator ANDERSON. Now, if they can produce this effect in the laboratory time after time after time, and people think they can produce it out in the open country, the Weather Bureau persists in saying there is nothing to it?

Mr. MCDONALD. Senator, you put words in our mouths which we do not use.

Senator ANDERSON. I just listen to you. There is a record being made, thank heaven.

Mr. MCDONALD. We do not use the expression at all that we think there is nothing to it. On the contrary, we filed in the record our serious interest in this, our intent, if we are given a mission and the funds to do it, to pursue this thing to a sound conclusion, but let us do it in terms of facts which are repetitive, reviewable facts and not simply the theories or the claims of somebody who says this is the fact because these things happened together.

Senator CORDON. You mentioned the matter of hanging out the wash on Monday and it raining on Wednesday.

Mr. MCDONALD. It probably was a very unfortunate figure of speech.

Senator CASE. I was just wondering, Mr. Chairman——

Senator WATKINS. Let me say this——

Senator ANDERSON. Senator Case.

Senator CASE. I was just wondering, Mr. Chairman, if the women in a certain community all hung their wash on Monday for 20 consecutive weeks and if then on 20 consecutive Wednesdays it did rain, would the Weather Bureau feel that there was no relationship between the two?

Mr. MCDONALD. You know where we would stand seriously on a question like that? We would want to try that for more than 20 weeks, because we know in weather—it is not as funny as it may sound—we know that in weather strange repetitions, strange sequences are so common, and there are repetitions back in history of unaffected weather, weather prior to any of these things being intro-

duced, and we will find weather patterns which are exactly like these patterns which occur after these things are begun.

I think we are justified in a degree of conservative agnosticism, if you please. It is not skepticism. It is agnosticism. We do not know.

Senator CORDON. The question is: Are you interested in finding out?

Mr. MCDONALD. Finally, in the business of trying to establish something about which we could say soundly under our sense of responsibility to the public we seek those things we believe we know so that we can hand them to the public with a confidence that we are working in the public interest.

Then, we would like to have a great deal more, although we might be very content to publicize results if the correlation, if the statistical investigation of the matter on the best facts available at the time—right now, before we know all about the weather—gave a high statistical value to this thing. But, as a matter of fact, we do not get high statistical values.

Senator CORDON. That is exactly what I think the Senator is driving at. The thing I am interested in is, you do not get the statistics—you have no method of getting the statistics.

Senator ANDERSON. And when someone tries to help them get the statistics, they are against the bill.

Mr. MCDONALD. We believe that the question will have to be settled finally in terms of statistics or not at all.

Senator CORDON. Then must there not be, whether it be the Weather Bureau, the Department of Commerce, or some other agency, some agency charged with the over-all duty and responsibility of informing itself, which is to say requiring those engaged in experiments to inform it of these experiments, of tabulating and evaluating all of the factors involved over the United States?

Mr. MCDONALD. We do not object to that at all.

Senator CORDON. You say you do not object to it?

Mr. MCDONALD. No.

Senator CORDON. Are you in favor of it? Do you believe it is in the public interest to do it?

Mr. MCDONALD. I will answer that question this way——

Senator CORDON. "Yes" or "no" will answer it for me.

Mr. MCDONALD. I will favor it unhesitatingly, and in the Weather Bureau; but with this proviso: We have to be recognized for the size of the job and given enough money to do a job and not left to do it on a shoestring.

Senator CORDON. There is no question about that.

Any other agency would have to have the necessary funds to do the job, but we have to establish first things first.

Mr. MCDONALD. I agree. I have no quarrel with that.

Senator CASE. Mr. Chairman, I wonder if the Weather Bureau has ever had an observer at any of these experiments or on any planes where they have used dry ice?

Mr. MCDONALD. Yes; we have conducted experiments ourselves in the field. We have had observers with Project Cirrus.

Senator CASE. How do you explain that when planes go up and with a number of clouds in the sky a plane may take the one nearest to it, seed it, and see visibly that the cloud begins to boil and finally

produces a concentration and eventually lets loose with rain, that that particular cloud does it and none of the other clouds on the same day within a general area——

Mr. McDONALD. I say, we would accept that as a result, as a cause, but then we also see this in our tests, we do the same thing with clouds, and instead of boiling we get a dissipation; we get a streak of no cloud; we have diminished the amount of cloud.

Senator CASE. Maybe you overdid it.

Senator ANDERSON. That could be overseeding, could it not?

Mr. McDONALD. We do not know. We do not know enough about the processes. There is a lot to be discovered.

Senator ANDERSON. If you do it 100 times and 1 time it boils too much and does not precipitate rain, and the next time it precipitates rain with a smaller quantity, could you not possibly draw a conclusion from that?

Mr. McDONALD. We would have to do a lot of testing and evaluating from it. We would not want to draw a hasty conclusion at all. That is not our way of doing business.

Senator ANDERSON. I am sure of that.

May I file with the committee at this time reports which we received on these three bills: on S. 222, from the State Department, from Commerce, from Treasury, General Accounting Office, and from Agriculture; on S. 5, from the General Accounting Office, from Commerce, and from Agriculture; and on S. 798, from Commerce, from Agriculture, and from the General Accounting Office.

(The reports referred to are as follows:)

MARCH 13, 1951.

Hon. ALLEN J. ELLENDER,
Chairman, Committee on Agriculture and Forestry,
United States Senate.

DEAR MR. ELLENDER: We have given careful consideration to the bill (S. 798) to authorize the Secretary of Agriculture to conduct research and experiments with respect to methods of controlling and producing precipitation in moisture-deficient areas, which you recently sent us for comments. This bill appears to assign primary responsibility to this Department for research into methods of inducing rainfall.

We are greatly interested, not only in the induction of rain or snow, but in the possibility of cloud dissipation or other devices to reduce windstorm, hail, and flood damage, and lightning activity, the latter being one of the important causes of forest fires.

We should like to have clear authorization to perform research in methods of weather control as it affects agriculture. In conducting such research we would plan to carry it on in close cooperation with the Department of Commerce. We suggest the desirability of the Department of Commerce having primary responsibility, or at least coordinating responsibility, in view of the scientific organization already at work on this problem in that Department, for research in weather control among Federal agencies.

We should prefer that the authorization of such research be to the Secretary of Agriculture, rather than to specific bureaus of the Department. This provision would be in line with recommendations of the Hoover Commission that authorities be vested in the heads of agencies.

We, therefore, suggest amending section 1 of the bill, as follows:

"SECTION 1. That the Secretary of Agriculture is authorized, by contract or otherwise, to conduct research and experiments to discover practical means of dissipating clouds so as to reduce lightning activity, curtail formation of hailstones and serve other useful purposes, and to ascertain the most practical use of the techniques and principles of artificial induction of precipitation in providing moisture for crops and pastures, prevention of forest fires and other purposes: Provided, that the Secretary of Agriculture, in the conduct of such research and experiments shall cooperate as closely as possible with the Department of Commerce."

With these amendments we favor enactment of the bill.

If the committee should see fit to include authority to contract as provided in the above amendment, it may wish to consider providing means of protecting contractors against claims which might arise in connection with carrying out contracts under this authorization.

The Bureau of the Budget advises that it has no objection to the submission of this report.

Sincerely,

C. J. McCORMICK,
Under Secretary of Agriculture.

MARCH 13, 1951.

Hon. E. C. JOHNSON,
Chairman, Committee on Interstate and Foreign Commerce,
United States Senate.

DEAR SENATOR JOHNSON: You have requested the views of this Department on S. 222, a bill to provide for the development and regulation of methods of weather modification and control.

The proposed legislation recognizes a problem which we believe requires the enactment of legislation to guide the future course of Federal and non-Federal action. It is clear that recent research and discovery in cloud physics has greatly advanced the understanding of the exact conditions under which clouds precipitate rain or snow. It has also charted the theoretical possibilities for practical application of this new knowledge to artificially induce local modifications of the weather at a desired time and place.

Specifically, S. 222 would provide for progress of (1) assisting and fostering private research and development, (2) federally conducted research and development, (3) Government control of experiments and operations, and of (4) administration. It provides for the establishment of a Weather Control Commission with subordinate divisions and committees. It provides for the licensing of measures for weather modification and control; enforcement of the provisions of the act; Government assumption of liability; and appropriations for carrying out the provisions of the act.

It is recognized that there has been recent growing interest on the part of various groups in the Nation in modification of weather. There is evidence that some individual States are contemplating State legislation in an effort to exercise some control over experiments and operations in this field.

There may be some question that significant modification of the weather is already practical on a considerable scale. In light of technical problems, the proposed creation of a somewhat complex regulatory commission may also be open to some question.

It would appear that further careful study needs to be given to the form of organization and extent of its powers in light of the present knowledge of this subject. The most important task would be that of correlating research and of exercising proper control over independent local efforts to modify the weather.

It is noted that a great deal of the emphasis of S. 222 is placed on the military significance of the work. This may be appropriate in view of national defense aspects. It should be recognized, however, that man-induced precipitation may most frequently be prompted with respect to the production of agricultural crops. We believe, therefore, that any form of organization established should provide for adequate representation of agricultural interests.

We appreciate the opportunity extended to this Department to review S. 222. If we can be of further assistance to you, please do not hesitate to call on us.

The Bureau of the Budget advises that, from the standpoint of the program of the President, there is no objection to the submission of this report.

Sincerely,

C. J. McCORMICK,
Under Secretary of Agriculture.

MARCH 13, 1951.

Hon. FREDERICK J. LAWTON,
Director, Bureau of the Budget.

DEAR MR. LAWTON: This is in reply to your request for the comments of this Department on the bill, S. 5, to provide for research into and demonstration on practical means for the economical production, from sea or other saline waters,

or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes.

We believe the discovery of economically feasible means of producing fresh water from sea water might afford large benefits to agriculture in certain water-deficit areas, and would also produce far-reaching benefits to the public in other respects. Also of great concern to agriculture are those aspects of weather control that involve cloud dissipation and other devices to reduce lightning, hail, flood, and windstorm damage. At the request of the chairman of the Senate Committee on Agriculture and Forestry, we have also prepared comments on S. 798, which authorizes this Department to conduct research on methods of controlling and producing precipitation. We have favored enactment of that bill, subject to certain amendments. A copy of our comments on S. 798 is attached.

If, however, the committees considering weather-control legislation prefer the enactment of this bill, S. 5, to further authorize the conduct of weather-control research in the executive departments, we suggest its amendment so as to authorize the Secretary of Agriculture to conduct research to ascertain the most practical use of the techniques of artificial induction of precipitation to provide moisture for crops and pastures, prevention of forest fires and other purposes, and to discover practical means of dissipating clouds so as to reduce damage from hligtning, hail, windstorm, erosion, and floods.

We believe that the bill also might well contain provisions that in their conduct of research in weather control the Departments of the Interior and Agriculture shall cooperate as closely as possible with the Department of Commerce, in view of experience and scientific staff available in the Weather Bureau of that Department. The possibility of utilizing the Department of Commerce as a coordinating agency for Federal research in weather control might well be considered.

With the changes suggested we would have no objection to enactment of the bill.

Sincerely,

K. T. HUTCHINSON,
Assistant Secretary of Agriculture.

GENERAL ACCOUNTING OFFICE,
Washington, March 14, 1951.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate.

MY DEAR MR. CHAIRMAN: Reference is made to letter, dated February 26, 1951, from the chief clerk of your committee, with respect to S. 5, Eighty-second Congress, entitled "A bill to provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes"; S. 222, Eighty-second Congress, entitled "A bill to provide for the development and regulation of methods of weather modification and control," and S. 798, Eighty-second Congress, entitled "A bill to authorize the Secretary of Agriculture to conduct research and experiments with respect to methods of controlling and producing precipitation in moisture-deficient areas." The letter states that your committee is considering S. 5, that S. 222 is being considered by the Committee on Interstate and Foreign Commerce, and that S. 798 is being considered by the Agriculture and Forestry Committee, but that hearings on the bills will be held jointly. The letter requests a copy of a report said to have been requested on S. 222 and invites this Office to have representatives at the forthcoming hearings, to observe and to testify, if desired.

The bill pending before your committee, S. 5, would confer upon the Secretary of the Interior authority to take such action as is set out therein to accomplish the purposes indicated in its title. This Office has no information as to the need for or desirability of the enactment of this bill and makes no recommendation with respect thereto. No request has been received here for reports on S. 222 or S. 798. However, under date of January 2, 1951, this Office made a report to the chairman of the Senate Committee on Interstate and Foreign Commerce on S. 4236, Eighty-first Congress, which bill was practically identical to the pending bill,

S. 222. Since this Office had no information concerning the purpose and need of the proposed legislation other than that contained in a statement by Senator Anderson and in pertinent articles by two scientists printed at pages 16475–16476 of the Congressional Record for December 8, 1950, no recommendation was made with respect to the enactment of S. 4236, Eighty-first Congress. Similarly, this Office has no special information with respect to any of the three bills here under consideration.

The suggestion contained in the letter from your committee that this Office might desire to have representatives at the hearings is appreciated but, since as stated above, this Office has no information which it is believed would be helpful to the committees having the said bills under consideration, such representatives will not be in attendance unless specifically requested.

Sincerely yours,

FRANK L. YATES,
Acting Comptroller General of the United States.

MARCH 2, 1951.

Hon. EDWIN C. JOHNSON,
Chairman, Committee on Interstate and Foreign Commerce,
United States Senate, Washington, D. C.

MY DEAR MR. CHAIRMAN: On December 12, 1950, you requested any comments which the Treasury Department might wish to offer concerning S. 4236, to provide for the development and regulation of methods of weather modification and control. This proposed legislation has been introduced in the Eighty-second Congress as S. 222.

S. 222 would establish a Weather Control Commission, composed of the Secretary of Commerce and four members appointed from private life by the President. The Commission would be authorized to conduct research and development activities relating to methods and utilization of weather modification and control. It could also conduct weather control operations and projects of benefit to the public interest and national security. The bill would make it unlawful for any person to engage in weather control activities except pursuant to license issued by the Commission.

The subject of the proposed legislation is not related to the activities of the Treasury Department, and the Department has no comments to make with respect to the merits of the bill.

Very truly yours,

THOMAS J. LYNCH,
General Counsel for the Treasury.

MARCH 14, 1951.

Hon. EDWIN C. JOHNSON,
Chairman, Committee on Interstate and Foreign Commerce,
United States Senate.

MY DEAR SENATOR JOHNSON: The following is in response to your letter of January 10, 1951, requesting comments of the Department of State on S. 222, the Weather Control Act of 1951, introduced by Senator Anderson.

The portion of the bill falling within the special competency of the Department of State is section 7 (International Arrangements). A canvass of the appropriate offices within the Department of State does not reveal this section to be in conflict with any international agreement, treaty, or convention to which the United States is a party. Further, there is no record of international incidents or claims involving the United States which have arisen from weather modification. It is suggested, however, that consideration be given to the modification of line 10, page 14 (sec. 6-b) to read "common defense, security, or other national interest," in order that other aspects of national interest, in addition to security and common defense may be embodied in the provision.

Since the urgency of the matter did not permit prior clearance with the Bureau of the Budget, copies of this letter are being transmitted to that Bureau.

Sincerely yours,

JACK K. MCFALL,
Assistant Secretary
(For the Secretary of State).

DEPARTMENT OF AGRICULTURE,
Washington, D. C., March 13, 1951.

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
United States Senate.

DEAR MR. ASTIN: This is in reply to your letter of February 27, respecting requests for funds and authorizations enabling this Department to carry on activities in the artificial induction of rainfall, weather control, and the extraction of potable waters from sources including sea water.

This Department has not requested appropriations specifically earmarked for use in any of these kinds of activities. The President's budget for fiscal year 1950 and fiscal year 1951 did carry an item of increase for research in forest fire-control research, part of which would have been used to experiment with methods of cloud dissipation to reduce the number of so-called dry-lightning storms which are the cause of so many forest fires in the Northwest. However, funds for these increased activities were not appropriated.

There is no legislation which specifically authorizes this Department to undertake research along any of the lines mentioned in your letter. We consider, however, that the McSweeny-McNary Act (Public Law 466, 70th Cong., approved May 22, 1928), which authorizes us to carry on forest fire control research, provides authorization for us to undertake weather control experiments which might disclose means of reducing forest fires.

We have undertaken no work along the lines mentioned in your letter except a very small amount of exploratory work on cloud dissipation to minimize lightning, as a basis for judging whether further activities of this kind might be justified.

Sincerely yours,

K. T. HUTCHINSON, *Assistant Secretary.*

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., March 14, 1951.

Hon. JOSEPH C. O'MAHONEY, *Chairman,*
Committee on Interior and Insular Affairs,
United States Senate.

MY DEAR SENATOR O'MAHONEY: Reference is made to your letter of February 27, 1951, relating to joint hearings on pending legislation in connection with artificially induced rainfall, weather control, and the salt water distillation program, in which request was made for information relating to previous authorizations or appropriations for such purposes.

There is attached a copy of a memorandum prepared by the Bonneville Power Administration on this subject, which memorandum may be of interest to the Committee on Interior and Insular Affairs.

Sincerely yours,

OSCAR L. CHAPMAN,
Secretary of the Interior.

DEPARTMENT OF THE INTERIOR,
BONNEVILLE POWER ADMINISTRATION,
Washington, D. C., March 8, 1951.

Memorandum.
To: Director, Division of Water and Power
From: Bonneville Power Administration
Subject: Investigation of Methods for Producing Rainfall

This is in response to your request for a report of Bonneville Power Administration's activity on the above subject.

Pursuant to discharge of the duties imposed upon him by statute and departmental order, the Administrator has reached substantial agreement on a contract providing for a survey of the feasibility of increasing run-offs in the Columbia River drainage basin to optimum by means of inducement of precipitation through artificial nucleation and cloud modification. Actual inducement of precipitation is not included in the survey.

The Administrator's authority is found in section 2a of the Bonneville Project Act, 16 U. S. C. sec. 832a, and Order No. 2115 of the Secretary of the Interior

which directs the Administrator "to make such surveys * * * as he may determine to be useful or appropriate in connection with the marketing of power."

The estimated cost of this investigation is $7,500 which will include a report by the contractor on the legal problems involved.

JOHN D. DAVIS,
Manager, Washington, D. C., Office.

DEPARTMENT OF COMMERCE,
Washington, March 14, 1951.

Hon. EDWIN C. JOHNSON,
Chairman, Committee on Interstate and Foreign Commerce,
United States Senate, Washington, D. C.

DEAR MR. CHAIRMAN: This letter is in further reply to your request for our views with respect to S. 5, S. 222, and S. 798, bills providing authority for Government assistance to the development of processes for producing water suitable for agriculture, industrial, and other beneficial uses from saline waters and for research and regulation of weather modification activities.

There is attached a statement of our views concerning these bills.

The Bureau of the Budget advises us that there would be no objection to the submission of these views. If we can be of further assistance in this matter, please call on us.

Sincerely yours,

THOMAS W. S. DAVIS,
Acting Secretary of Commerce.

VIEWS OF THE DEPARTMENT OF COMMERCE WITH RESPECT TO S. 5 AND RELATED BILLS TO ASSIST IN THE DEVELOPMENT OF PROCESSES TO INCREASE THE AVAILABILITY OF USABLE WATER FROM SALINE WATERS AND THE ATMOSPHERE, AND FOR OTHER PURPOSES

S. 5 would authorize the Secretary of Interior to conduct research on the production from saline waters of water suitable for agriculture, industry, municipal and other beneficial uses, and on the production of water from the atmosphere.

S. 222 would establish a Weather Control Commission with broad powers to conduct research in the field of weather control and rain making and to license others to perform these functions.

We believe generally that Government research and development in the field should proceed and we therefore favor the general objectives of these bills.

In drafting S. 5, the importance of the economic feasibility of processes developed for obtaining usable water from saline waters is stressed. We share this view and believe this to be the most important aspect of this development. For this reason we recommend that consideration be given to imposing a safeguard in the bill to provide that, to the fullest extent practicable, cost studies of any proposed method be made before a plant for the demonstration of that control is erected.

We also recommend that consideration be given to the fullest utilization of water resources presently available. Fresh water in vast quantities is discharged into the oceans from the rivers of the United States. Utilization of this river water, if possible, would, in large measure, eliminate the ocean-side costs of obtaining additional salt-free water, while transportation costs would, depending on the area, remain the same as for processed saline waters. Consideration should also be given to the increased use of sewage effluent for agricultural purposes, which would permit greater utilization of natural water resources for domestic and other uses. It is not clear that research on these two aspects of the problem would be authorized by S. 5, and the legislative history of this bill or the language therein should, in our opinion, be written to authorize their inclusion.

With respect to controlled production of water from the atmosphere, or rainmaking, we enter the area of speculation and uncertainty. Acting under authority of Public Law 691, Seventy-ninth Congress (49 USC 603, 60 Stat. 944), and Public Law 657, Eightieth Congress (62 Stat. 470) the Weather Bureau has conducted extensive research in weather control and rainmaking. This research and experimentation does not support the conclusion that significant amounts of rainfall can be artificially induced in addition to that which would have occurred naturally in the locality. We had contemplated that this research would be continued until the fullest possible knowledge of the subject is gained.

If we assume the development of artificial rain-making, we are of the opinion that the processes developed will effect climatic changes in the area directly controlled and elsewhere. Certainly the Weather Bureau, and the Department of Commerce generally, would have a most direct and immediate interest and responsibility in these effects. In the light of this interest and responsibility and in the light of the research already carried on by the Department in the field, which has resulted in considerable data (see The Thunderstorm, etc., 1949, available at Superintendent of Documents, U. S. Government Printing Office), we believe that primary responsibility for furthering weather control should be continued in the Department of Commerce.

We recognize the potential danger of unrestricted experimentation in the control of weather, and of restrictions which are not uniform, and therefore recommend that, in addition to conducting such experimentation, the agency should be empowered to license activities in the field giving consideration to the exclusion by class from the requirement of licenses, such localized activities as fog dispersal at airports, frost prevention in orchards, etc. We would also favor the enactment of provisions safeguarding contractors hired by the Government to carry out experimentation in this field from liability arising out of their activities. We believe that the state of development in this field does not warrant further Government action.

(The report of the Department of the Army on S. 5, S. 222, and S. 798 which follows was received after the close of the hearings.)

DEPARTMENT OF THE ARMY,
Washington, D. C., May 28, 1951.

Hon. EDWIN C. JOHNSON,
Chairman, Committee on Interstate and Foreign Commerce,
United States Senate.

DEAR SENATOR JOHNSON: Reference is made to your recent request to the Secretary of Defense for the views of the Department of Defense with respect to S. 222, a bill to provide for the development and regulation of methods of weather modification and control. Although your committee has not requested an expression of the views of the Department of Defense with respect to S. 5, a bill to provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes, and S. 798, a bill to authorize the Secretary of Agriculture to conduct research and experiments with respect to methods of controlling and producing precipitation in moisture-deficient areas, for the convenience of the subcommittee which is considering those bills together with S. 222, and at the suggestion of the Secretary of Defense, the views of the Department on all three bills are incorporated in this report. The Secretary of Defense has delegated to this Department the responsibility for expressing the views of the Department of Defense on the mentioned bills.

The Department of the Army, on behalf of the Department of Defense, favors the enactment of S. 5, subject to the comments and recommendations set forth below, and is opposed to the enactment of S. 798 and S. 222 in their present form.

S. 222 sets out findings intended to establish the importance of the matter of weather modification and control; the proposed policy of the Congress, among other things, to regulate and supervise experiments and operations designed to modify and control weather; and the stated purpose of the bill, which is to effectuate the policies and establish certain major programs. The bill also provides for the establishment of a Control Commission much along the same lines as the Atomic Energy Commission, with advisory and liaison committees.

S. 5, with one exception, is substantially the same as S. 1300, Eighty-first Congress, and in general sets forth the policy of the Congress to provide for the development of economically feasible means of producing from sea water, other saline waters or from the atmosphere, water of quality suitable for agricultural, industrial, municipal, and other beneficial consumptive uses. To this end, the Secretary of the Interior is authorized to conduct research and development work, to acquire patents, inventions, and other property, to cooperate with other governmental departments, agencies, or instrumentalities, and to request other Federal departments, agencies, and instrumentalities to provide assistance. Certain authority is also granted to the Secretary of the Interior to dispose of water and other products produced as a result of his operations under the bill. Authoriza-

tion for appropriations of up to $25 million is contained in the bill, as well as certain provisions for indemnification, periodic reports to the Congress, and issuance of rules and regulations.

S. 798 directs the Secretary of Agriculture to conduct research and experiments and to take such further action as may be necessary to perfect methods of causing rain to fall in deficient areas. Other Federal departments are directed to make their records and data available to the Secretary of Agriculture. The bill also contains an authorization for appropriations.

The armed services have been engaged in basic studies of weather modifications which have led to certain techniques now being tested. Experiments and tests to date have had some possible significance but their results cannot be considered conclusive as yet. The results to date indicate that under favorable conditions some local changes can be produced by artificial means. This is generally agreed upon by most independent experts. There is, however, considerable controversy as to whether cloud modification can effect major weather changes; for instance, there appears to be no hope at the present time to break a genuine drought by this means. The evidence that some changes can be induced is sufficiently strong, however, to make it desirable to explore further possible tactical and strategic implications. Current and prospective tests by the services also have possible military applications the nature of which necessarily constitute classified information at this time.

There is a considerable element of doubt concerning the validity of results to the present because of cloud-seeding activities of others, which may have had some effect on the tests conducted by the armed services. It is generally agreed that methodical, systematic, and coordinated research should be encouraged. Large operations by irresponsible persons could seriously upset research activities of serious students in this field. Legislation which would protect the validity of experiments by providing for coordination of effort and, at the same time, not hamper vigorous prosecution of valid research is desirable. Such legislation should also provide means for protecting the public against the great danger of victimization, especially farmers and others who need water from time to time. The protective mechanism which is required should, however, be commensurate with the needs and at present it appears that this mechanism should be relatively simple and easily enforceable.

It thus appears that there is no basic difference of opinion between the armed services and the author of S. 222 as to the necessity of control of experiments in weather modification and control; the services feel, however, that the extent of valid scientific knowledge on the subject is not yet sufficient to justify a large and expensive control ozganization or the degree of regulation contemplated by the bill. It is believed that the mechanism to accomplish the necessary control could be established within the framework of presently existing Government agencies. Emphasis at this time should be on research with only so much control as may be necessary to ensure coordinated effort and to present indiscriminate and irresponsible attempts at cloud modification. This control could be provided for by a simple bill which would vest in an existing agency, such as the quasi-judicial Interstate Commerce Commission, authority to issue regulations setting forth terms and conditions on which all seeding may be conducted, including a requirement that all persons, firms, or corporations engaged in the seeding of clouds shall furnish specified information and findings to the Weather Bureau.

Such a bill should also give to all Government agencies engaged in research in this field authority to indemnify their contractors against liability for all damage directly resulting from their research. Appropriate language for such a section is contained in section 10 of S. 222, which provides generally for broad assumption by the Government of liability for damages resulting from the performance of contracts relating to weather modification or control. This section is broader than the provisions of section 5 or S. 323 (a bill to facilitate performance of research and development work by and on behalf of the military departments) in that it provides for sole responsibility by the Government for damages, and that no cause of action with respect to any such claim for damages may be maintained against the contractor but shall be solely by suit against the United States in the Court of Claims. The provisions of section 10 are not objectionable, even as broad as they are, except the clause set forth on lines 2 and 3 on page 21, "whether due to the negligence of the contractor or otherwise." It is believed that the Government should not be an insurer of a contractor so as to protect him on account of his own negligent acts. The quoted clause should be stricken out from the section. In addition, there should be inserted in whatever section is equivalent to section 10 a provision authorizing settlement of claims by the head

of the contracting agency and in such case, the second proviso of section 5 of S. 323 should also be included in the bill.

It is believed that a bill containing the foregoing provisions would be sufficient to meet present needs. Interested Government agencies would undoubtedly form a coordinating committee under the Interdepartmental Committee on Research and Development, or some other existing agency, who would advise the regulatory body, coordinate research activities of Government agencies, and review all the developments and recommend to the regulatory agency additional legislation as required.

The Federal Trade Commission under its authority to prevent "unfair or deceptive acts or practices in commerce" could be requested to exercise its authority with respect to false claims made by professional "rainmakers." This would prevent, to a great measure, the victimization of farmers and others who need water from time to time and who might be deceived by extravagant or false claims.

With respect to S. 5, which is described above, it is believed that express authorization to conduct research in cloud modification is not necessary for any Federal agency having an interest in the field. If the authority is not actually needed, it should be deleted from S. 5 because it might cast doubt on the authority of other agencies to engage in similar activities.

S. 798 is based upon the premise that rain can be made where and when wanted. To this extent the bill is misleading. Furthermore, this bill would accomplish very little in that adequate authority already exists in all agencies having interest in the field for the conduct of research in cloud modification. The provisions of section 2 (a) which requires all agencies to make all data relating to cloud modification available to the Department of Agriculture might be seriously detrimental to the national security because it might require the furnishing of such data even though classified for military security reasons.

The Department of the Army, in behalf of the Department of Defense, recommends that S. 5 be modified in accordance with the foregoing views and, as thus modified, recommends its enactment. The Department does not recommend enactment of S. 798 or S. 222.

The fiscal effect of S. 222 is unknown to the Department of Defense. The fiscal effect of S. 5 is apparent from section 8 thereof, which authorizes appropriations not to exceed $25 million. The fiscal effect of S. 798 is also unknown to the Department of Defense.

This report has been coordinated among the departments and boards of the Department of Defense in accordance with procedures prescribed by the Secretary of Defense.

The Bureau of the Budget advises that there is no objection to the submission of this report.

Sincerely,

FRANK PACE, Jr., *Secretary of the Army.*

Senator ANDERSON. May I say, as far as I am concerned, there is no difference of opinion between Senator Case and myself, or Senator O'Mahoney and myself, on these bills. I do not care whether Agriculture does it, Commerce does it, whether the Army does it, the Navy does it, or the Air Force does it, as long as somebody keeps the score and tries to find out what happens, and I think Senator Case feels the same way about it. He has had experience.

Senator CASE. Except with this modification: That I would want it in the hands of somebody who is going to try to get some results and not merely try to find a negative answer.

Senator ANDERSON. I think so, too.

Mr. MCDONALD. Might I file for examination of the committee or any of its staff a collection of reports and papers?

Senator ANDERSON. Is Research Paper No. 31 there?

Mr. HALL. Yes.

Mr. MCDONALD. I presume so. Not all of them are by the Weather Bureau. There is outside opinion in there. We do not stand alone in this business. There is a conservative position about

it, and a lot to learn before we are in a position to state sound conclusions. That is the opinion of meteorologists, a number of them.

(The documents referred to are as follows:)

UNITED STATES DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, D. C., July 7, 1947.

CIRCULAR LETTER NO. 55–47

(To all first-order stations)

Subject: Artificial inducement of precipitation.

Although artificial inducement of precipitation has often been attempted, it is only recently that experiments have been performed which offer some hope for success under certain special atmospheric conditions. Dr. Irving Langmuir and Mr. V. J. Schaefer of the General Electric Co., Mr. E. S. Ellison of the Weather Bureau Station in Portland, Oreg., and Australian meteorologists, have conducted experiments wherein supercooled water clouds were "seeded" by the dispersal of dry ice (solid CO_2) particles from aircraft. It is the purpose of this circular letter to describe briefly what is known of the scientific background of the phenomenon and to outline the policy of the Weather Bureau with regard to the participation in such experiments by Weather Bureau personnel.

SCIENTIFIC BACKGROUND

From evidence accumulated, both in the laboratory and in the field, there is no doubt that supercooled water clouds can be transformed into ice crystal clouds, and that the ice crystals can grow to such size that they fall from the cloud as precipitation. There is, however, quite a gap between this simple but important fact and the production of appreciable or even measurable amounts of precipitation. For example, a supercooled cloud 3,000 meters thick, with the rather high water content of 1 gm/m^3, will, if it is seeded and remains stationary, deposit 0.12 inch of melted snow if all its water is transformed into ice crystals which fall to the ground without evaporation. Actually of course the moving cloud will deposit its precipitation over an area much greater than its own, and the measured precipitation at one location will be even less.

According to Dr. Langmuir's researches, seeding creates myriads of sublimation nuclei or "ice germs"; and each ice germ may grow to an ice crystal and fall as precipitation if there is sufficient moisture available. Ordinarily there is not sufficient moisture in the treated cloud to gather around each and every ice germ and cause it to grow to sufficient size to fall. The moisture content, however, may be increased by convection and/or advection. But when additional moisture (either liquid or vapor) replaces the seeded portion of the cloud, there will be little or no seeds available in the new cloud formations to transform it into an ice cloud. Hence it is very important for spread of the precipitation area that the ice germs diffuse to unseeded portions of the cloud by mixing or convective processes. The rapidity of this diffusion is a subject of current investigation. The transformation of a supercooled water cloud to an ice crystal is accompanied by the liberation of the heat of fusion. A simple calculation will show that when a cloud of liquid water content 1 gm/m^3 is changed to ice at 10,000 feet, enough heat is released to warm it up 1/3° C., which seems too small to have any appreciable buoyancy effect in causing the cloud to "boil" upward to produce heavier precipitation. Silver iodide also has ice nucleation properties and has the advantage that the nuclei thus formed do not evaporate or melt and so can remain for long periods regardless of the temperature until they come into the presence of supercooled water droplets and produce their effect. On the other hand, the nuclei produced by dry ice are minute ice crystals which evaporate and melt when the air is dry or the temperature rises above freezing. According to Langmuir, such ice nuclei are produced not only by frozen CO_2 but by any material at temperatures below −35° C.

OPERATIONAL DETAILS

The cloud to be treated should be a water cloud at subfreezing temperatures, the thicker the better, and with optimum temperatures probably between −10° C. and −15° C. The dry ice should be in the form of pellets about one-fourth inch in diameter. If it is desired that the CO_2 seeds drop to a lower supercooled

cloud located several thousand feet below the level of the aircraft, about half of the pellets should be somewhat larger, one-half inch to three-quarters inch in diameter. Dr. Langmuir's computations show that a spherical pellet of four-tenths cm. diameter will fall in air at −20° C., 1,100 meters before complete evaporation. The CO_2 should be discharged from the aircraft at the rate of about 1 pound per mile. No information is available regarding the field application of the silver iodide.

POLICY

As news of the experiments on artificial inducement of precipitation has spread, there have naturally arisen requests for similar experiments to be carried out, particularly in those regions where the water supply is of critical importance to human activity. When local groups desire to conduct such experiments, they look to the Weather Bureau for guidance and leadership. Since considerable publicity often accompanies these attempts to induce precipitation artificially, we need to stress in our relations with the public and interested local groups that, although some very promising experiments have been made, we do not yet know enough about the processes involved to predict whether significant or even measurable amounts of precipitation can be produced; very specialized atmospheric conditions are apparently required to produce even a trace of precipitation.

Extensive experiments are under way under Government sponsorship. The elaborate equipment and scientific controls being employed by the Government-sponsored project to evaluate results of the seeding experiments will be very difficult to duplicate elsewhere. The Weather Bureau does not wish to control or restrict constructive scientific experiments, particularly on such an important question as increasing the water supply in critical areas. If Weather Bureau officials are asked to participate in experiments to produce precipitation artificially, the scientific facts presented in this circular letter should be made known to the people concerned. If after this is done they still wish to go ahead, the central office should be informed of all details, including the proposed site of seeding, in order that official authorization may be issued and the best possible arrangements be made for cooperation.

F. W. REICHELDERFER, *Chief of Bureau.*

DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, August 26, 1947.

CIRCULAR LETTER NO. 75–47

(To all stations)

Subject: Artificial inducement of precipitation.

Effective immediately and until further notice all official Weather Bureau statements for publication on the results of articial inducement of rain or snow will be cleared with the central office before release. This applies in particular to observations or conclusions with reference to the results of tests of artificial nucleation by means of dry ice or other reagent. In cases of urgency where clearance for immediate publication is necessary, field officials are authorized to obtain clearance by telegram or telephone call to the central office but these cases should be kept to the minimum.

Prior clearance is not necessary for statements containing the substance of Circular Letter 55–47 in reply to specific inquiries for information for publication but in every case Weather Bureau officials should be noncommittal as regards the immediate practical results or possible commercial value of artificial production of rain or snow. As stated in previous correspondence, it is the policy to discourage sporadic experiments which are without systematic planning and scientific supervision. In many cases unrelated experiments would lead to premature and erroneous conclusions. Local enthusiasts who desire to make immediate experiments should be informed that the Federal Government is carrying on very extensive research in this field and will obtain conclusive evidence as soon as possible; also, that uncoordinated local tests may delay rather than hasten the development. There are legal questions and other problems involving conflicting views and interests which may cause serious trouble.

The reason for requiring clearance before publication of opinions or conclusions as to rain-making experiments is that the implications and probable legal conse-

quences of recent public statements on this subject have caused concern among the several departments of Government interested in this research. Editing of statements for publication and coordination with general plans in this field will assist in avoiding the difficulties referred to. When newspaper representatives press for an immediate statement on the results of tests, they should be informed that the results will have to be studied in relation to radiosonde observations before definite statement can be made since meteorological conditions may be such that rainfall would have occurred without artificial aid. This will give an opportunity to obtain clearance as requested herein.

It is not desired to place unnecessary restrictions on the relationships between local officials and the press but it is necessary to have some degree of national coordination and to avoid unilateral conclusions which may be misleading and result in serious local and even national consequences. It continues to be the policy to discourage local tests which are not part of the official research program. Weather Bureau officials should act as observers in local tests only after clearance with the central office and as a last resort when it is obvious that the test would otherwise be conducted without Weather Bureau observers.

F. W. REICHELDERFER, *Chief of Bureau.*

DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, October 31, 1947.

CIRCULAR LETTER NO. 98–47

(To all stations)

Subject: Legal aspects of rainfall allegedly produced by artificial means.

Because of the intense popular interest in artificially induced precipitation and the susceptibility of the subject to sensational headlines, the press and radio are inclined to headline comments on this subject in a manner open to misinterpretation. Several instances have occurred during recent weeks where careful statements by Weather Bureau officials in reply to questions have been inaccurately reported and in some cases implied a meaning opposite to that intended. Some of the reports might carry serious legal implications. To safeguard the Federal Government, the Bureau and its employees against legal involvenfent, the following directive is hereby adopted.

> Weather Bureau officials and employees in general should not express opinions for publication, either directly or in letters and conversations, with persons who might make the statements public, if such statements might form the basis for legal action of any kind. This applies particularly to statements implying that artificial nucleation was the casue of precipitation or other modification of the weather in forms that might cause damage to private property or private interests.
>
> The directive does not apply to statements of meteorological observations and other factual data in connection with artificial nucleation experiments when the statements do not express opinion as to whether precipitation or other weather changes have been the result of artificial techniques or natural processes. Moreover, the directive does not apply to intramural discussions of these subjects with other officials in the conduct of official business in connection with artificial nucleation and other experimental projects.

These instructions are not intended to limit or restrict except with reference to legal implications. In order that the policy of the Bureau may be understood and not be misinterpreted as indifferent or negative with respect to this important subject, the following brief restatement of policy is given.

The practical possibilities of articial inducement of precipitation are still unknown. It is highly desirable to determine the possibilities without delay. The Bureau therefore has inaugurated a research program and is cooperating closely with other research agencies in experiments to determine the possibilities. The Bureau's policy therefore is one of maintaining an open mind and assisting in a constructive research program in this field. It is also desirable to avoid a negative attitude on this subject when questions are received from the public or representatives of the press. It is appropriate to state that the Weather Bureau is vitally interested in the subject and is actively participating in the research program. It is also appropriate to release factual data and authenti-

cated observations of such information as amount of precipitation, unless release has been specifically prohibited. The important point is to avoid statements that might be used to fix responsibility for storm damage. When such questions are asked, it may be stated that the causes have not been accurately determined and we do not have enough information to say whether the results were due entirely to natural processes or not.

The provisions of Circular Letters No. 55–47 dated July 7, 1947, and No. 75–47 dated August 26, 1947, remain in effect.

F. W. REICHELDERFER, *Chief of Bureau.*

DEPARTMENT OF DEFENSE,
OFFICE OF PUBLIC INFORMATION,
Washington, D. C., July 19, 1950.

(Press Branch fact sheet)

PROJECT CIRRUS

WHY PROJECT CIRRUS?

Weather always has been an important factor in military operations, and by the same token, weather forecasts are important. Weather affects men; it affects ground, sea, and air transport; it affects communications and radar; it affects tactical plans; it affects artillery fire.

In large measure, "weather" is associated with the action of clouds although clouds themselves may be what they are at a given moment because of many other meteorological factors.

This is a "fact sheet" on project Cirrus, a study that was begun in 1947 by the armed services to learn more about clouds and how to change them in ways that would have military application. With the advent of radar as a tool in weather forecasting, it also became important to know more about clouds, in order to interpret radar data more fully.

WHAT IS PROJECT CIRRUS?

Project Cirrus is a cooperative research investigation in cloud physics sponsored by the Signal Corps of the United States Army and the Office of Naval Research, in consultation with the General Electric Co. Airplanes used in experiments are provided by the United States Air Force. It is intended to obtain a more complete understanding of the physical processes in the atmosphere associated with the formation, growth, and dissipation of clouds.

The work of project Cirrus is guided by a technical steering committee consisting of the following: Chairman, Dr. Michael J. Ference, Jr., Signal Corps Engineering Laboratories, Fort Monmouth, N. J.; Dr. C. J. Brasefield, also of the Signal Corps Engineering Laboratories; Lt. Max Eaton, Office of Naval Research, Washington, D. C.; Col. N. C. Spencer, United States Air Force Air Weather Office, Washington, D. C.; and Lt. Col. J. Tucker, Research Division, Headquarters, United States Air Force, Washington, D. C.

WHAT ARE THE SCIENTIFIC ACTIVITIES OF PROJECT CIRRUS?

Project Cirrus, initiated by the Armed Forces, has utilized the services of Dr. Irving Langmuir and Dr. Vincent J. Schaefer in research, including fundamental laboratory studies, development of special techniques, and instrumentation using the fact that supercooled water droplets could be converted into ice crystals readily and inexpensively. This discovery is considered fundamental, since the widely accepted theory of precipitation proposed by T. Pergeron and W. Findeisen, predicted that supercooled clouds are unstable and would be modified in the presence of ice crystals.

It is known that very small particles in the air act as the nuclei around which droplets and ice crystals form. The General Electric scientists discovered methods for injecting such nuclei into clouds rapidly and efficiently. They thereby opened up an entirely new area for military research and possible exploitation. As a result of these early experiments of Drs. Langmuir and Schaefer, studies on the nature of clouds, their formation, their dissipation, their structure, and possible modification by artificial means were started. To supplement this broad study, specific research was undertaken to determine such important properties

of clouds as the liquid water content, temperature, degree of turbulence, size of cloud droplets, number of ice crystals or freezing nuclei present, and finally the concentration of condensation nuclei. In addition to these field experiments, laboratory research was required to study the chemical and physical properties of artificial nuclei, and to increase our knowledge of the basic processes of precipitation.

WHAT ARE THE SCIENTIFIC ACCOMPLISHMENTS OF PROJECT CIRRUS TO DATE?

It is still too early to appraise the full scientific import of the research. However, during the past 3 years that Project Cirrus has been in existence, a number of fundamental contributions have already been made to our understanding of the processes that go on within clouds. Some of the more important of these contributions which have been accepted as part of the meteorological literature are:

1. It is an experimental fact that a supercooled cloud, i. e., a cloud containing water droplets whose temperature is below freezing, can be converted into an ice crystal cloud by the use of either dry ice pellets or silver iodide nuclei. It has been possible on occasion to create holes in supercooled layer-type or stratus clouds so that the ground beneath could be observed. This would be obviously useful to both military and commercial aircraft, for making landings or parachute drops through an overcast. Inasmuch as this type of cloud contains very little liquid water, however, the amount of precipitation that would reach the ground as a result of seeding would, in general, be quite negligible. In spite of the marked success in modifying supercooled clouds, there are a number of questions which still remain unsolved—namely, the quantitative relationship between the amount of the nucleating agent necessary for efficient dissipation of a cloud and the thickness of the cloud, the amount of water within the cloud, the turbulence within the cloud, etc.

2. It has been observed that the number of effective natural ice nuclei present within the atmosphere varies over a tremendous range, from a few nuclei per cubic foot to several million per cubic foot. This observation has focused attention on the possibility of accomplishing large-scale cloud modification by artifically increasing the effective nuclei in the atmosphere.

3. It has been learned that these natural nuclei, so essential for rainfall, are quite temperature-dependent. Certain nuclei are effective in converting water droplets to ice crystals at temperatures slightly below the freezing temperature, while other nuclei do not become effective until the temperature drops to very low values. Since both silver iodide nuclei and those formed by dry ice are effective near the freezing temperature, it should be possible to modify a cloud at a much earlier stage of its development.

4. It has been verified that water droplets within a cloud will convert spontaneously into ice crystals when the temperature of the cloud reaches 40° below zero C. (which is normal freezing temperature).

5. Some engineering data useful for the design of military radar weather equipment have been obtained from these studies.

6. Development of a useful theoretical model for precipitation processes based on the growth and fragmentation of water drops and ice crystals has come out of the work.

Paralleling this research, there have been numerous equipment and technique developments that have value beyond the applications of this project. For example, there have been developed:

1. A special aircraft thermometer to measure true air temperatures in the presence of water droplets.
2. An apparatus for measuring size of cloud droplets.
3. An apparatus for determining the liquid water content in a cloud.
4. A technique for detecting ice crystals in the presence of water droplets within a cloud.
5. Techniques for evaluating automatically the concentration of nuclei in the atmosphere.
6. Methods for measuring the upward drafts within clouds.
7. Techniques for collecting ice crystal replicas in the clouds.
8. Techniques for photographing clouds and analyzing changes due to artificial nucleation.
9. Methods for generating artificial nuclei.
10. Laboratory techniques for studying the growth and fragmentation of large water drops.

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Not enough is known of the natural processes in the atmosphere to be able to draw positive conclusions as to the effects of artificial nucleation except as noted previously. This is not an unreasonable scientific statement when one considers that atmospheric processes are in a continual state of flux and it is difficult, if not impossible, to obtain two identical weather situations for a control experiment. Therefore, many meteorologists feel that it is necessary to employ statistical experimentation over an extended period of time in order to draw definitive conclusions on the effectiveness and usefulness of artificial nucleation.

The question "Can you make it rain?" has received an answer in the affirmative in many experimental instances where atmospheric conditions were suitable, but the question of how much precipitation can be artificially induced or if the amount would be of any economic significance is yet to be determined.

It is the opinion of many meteorologists that a complete answer will come only after several years of careful experimentation because (1) it is not known what minimum number of nuclei are necessary to cause a cloud to precipitate its moisture, and (2) how frequently nature provides this minimum number.

Only through a more complete understanding of the complex natural phenomena associated with cloud and storm formation, growth and dissipation can the final answers as to potential military and economic usefulness be obtained. Results to date amply justify the necessity for continued efforts in this field.

DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, July 27, 1950.

CIRCULAR LETTER No. 54–50

(To all first-order and CAA stations)

Subject: Furnishing of weather data obtained from official thermometers and rain gages to private individuals or agencies.

It has come to the attention of the central office that various private agencies engaged in rain-making experiments or the evaluation of cloud seeding programs have recently requested weather observing stations to report daily precipitation on a weekly basis directly to them.

Inasmuch as daily precipitation data are available, to these private agencies in the form of synoptic reports on teletype circuits, it will be unnecessary for CAA and the Weather Bureau first-order stations to comply with requests of this nature.

Since cooperative weather stations also have been requested to make daily reports of precipitation on a weekly basis to these agencies, the policy regarding compliance of cooperative observers with such requests is given below for information of all stations and for relay to the cooperative observers by the Section Center.

Cooperative observers who desire to make reply to private inquiries for weather data may furnish the information if they wish but they are not under obligation to do so insofar as the Weather Bureau is concerned. The official duties of the cooperative observer consist only of the observations and reports requested directly by an official of the Bureau. Other services including replies to inquiries from persons or organizations outside the Weather Bureau are left entirely to the discretion of the cooperative observer and are not official services unless explicitly authorized by the Bureau.

We wish to cooperate in every way practicable in worth while research and development by other public institutions or by private agencies but we do not desire our cooperative observers to engage in outside meteorological services or reply to outside inquiries if the additional work is a burden to them or if it interferes in any way with their official observations and reports to the Bureau.

The Weather Bureau is deeply indebted to its regular cooperative observers for their regular voluntary observations and reports which comprise the material for the climatological records of the United States. We do not wish to have their official connection with the Bureau become the source of annoying inquiries from private agencies or the means of adding excessively to their work. Any work they perform in response to unofficial inquiries is wholly a matter of their personal choice.

F. W. REICHELDERFER, *Chief of Bureau.*

[From Bulletin of the American Meteorological Society, vol. 31, No. 9, November 1950, pp. 346, 347]

On the Results of Recent Experiments in the Artificial Production of Precipitation

The potentialities of artificial weather control and modification have excited the imagination of all of us. Rain making, as a result of artificial nucleation, has been particularly publicized during the past many months. As a result, Federal, State, and municipal authorities have been besieged with requests to make rain, to stop rain, to put out fires, to destroy hurricanes, to eliminate icing, hail, and fog, and even to create major climatic changes. The lack of authoritative and quantitative information on this subject is most apparent. Recently the Council discussed this matter and strongly urged that a statement on the present status of rain making be obtained from a group of prominent scientists, who have followed rather closely the technical documentation of development in this field. This letter is in answer to my request for such a statement from Professors Haurwitz, Emmons, Wadsworth, and Willett.—D. N. Yates, president, American Meteorological Society.

August 16, 1950.

Brig. Gen. D. N. Yates,
President, American Meteorological Society,
Room 4E 336, The Pentagon, Washington, D. C.

Dear General Yates: In answer to your request for a discussion on the evaluation of claims of artificial rain-making we are submitting herewith a brief description of two possible approaches to the problem, together with our opinion of claims of success made thus far.

The formation of atmospheric ice and water particles and their coagulation are still only imperfectly understood despite the great advance in recent years which is to a large measure due to the work of Langmuir, Schaefer, and their coworkers. For this reason and because of the impossibility of controlling the atmosphere or of forecasting accurately what would have happened if artificial disturbances had not been introduced, it is extremely difficult to evaluate claims of success in rain making.

One approach to this problem is to estimate the probable precipitation that might have been expected from the prevailing weather pattern in the normal course of events at the time of the experiment. From this point of view it may be said that at the time of certain experiments in New Mexico the weather conditions were quite favorable and adequately explain the moderately but by no means exceptionally heavy amounts of precipitation that occurred. It cannot be proved to what extent, if at all the future weather development was altered by the occurrence of precipitation once it was initiated, nor is it possible to decide how much of the precipitation which occurred at the stations individually should be attributed to seeding. In the case of the heavy rainfall during the past winter in the Mississippi Valley it is even more difficult to judge the likelihood of any effect of seeding on the weather pattern. Certainly it can be said that the weather pattern and rainfall of this period were quite similar to a number of corresponding periods in the past, and fit very naturally and normally into the rather unusual Northern Hemisphere weather pattern of the past winter.

A second approach to the problem is essentially statistical and involves an estimation of the probability of the occurrence of the phenomena by chance alone. To this end a complete analysis of the entire situation must be made, starting with a statistical analysis of the original data on moisture distribution, winds, and rainfall in relation to topography. Topography alone can be expected to produce a certain similarity in precipitation patterns on different days. It would be necessary also, because of the connection (serial correlation) that exists within and between weather patterns, to go back over the records and evaluate from past data the probabilities of various degrees of agreement between weather patterns. To be sure odds have been quoted by various investigators, but in no case have these necessary precautions been observed, and therefore the odds cited cannot be accorded scientific credence.

It is the considered opinion of this committee that the possibility of artificially producing any useful amounts of rain has not been demonstrated so far if the available evidence is interpreted by any acceptable scientific standards.

B. HAURWITZ,
Chairman, Department of Meteorology,
New York University.

GARDNER EMMONS,
Research Associate, Department of Meteorology,
New York University.

G. WADSWORTH,
Professor of Mathematics,
Massachusetts Institute of Technology.

H. C. WILLETT,
Professor of Meteorology,
Massachusetts Institute of Technology.

UNITED STATES DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, D. C., December 22, 1950.

CIRCULAR LETTER NO. 95–50

(To all stations)

Subject: Artificial rain making.

The Bureau wishes to be informed of any artificial rain-making tests or experiments, or commercial rain-making ventures that might be conducted. Until further notice, field stations are accordingly requested to inform the central office (attention S. R. and F. Division) briefly by mail whenever activities of this kind are contemplated or are in operation in their areas. The report (in duplicate) should include information on the site and dates of operations, the name of the operator, and any other pertinent facts in the case.

F. W. REICHELDERFER, *Chief of Bureau.*

UNITED STATES DEPARTMENT OF COMMERCE,
WEATHER BUREAU,
Washington, March 6, 1951.

CIRCULAR LETTER NO. 10–51

(To all stations)

Subject: Statement on artificial rain making.

The following statement has been issued for official use in Washington and is transmitted to field stations for information as to the Weather Bureau's position on this subject and as a guide to field officials in answering inquiries:

It has been demonstrated conclusively both in the laboratory and in the atmosphere that cloud droplets at temperatures below freezing can be converted into ice crystals by "seeding" with dry ice, silver iodide and other nucleating agents. This is an initial step in "making rain" by artificial means; in fact, the natural conversion of supercooled cloud droplets into ice crystals or snow is one of the processes by which rain commonly occurs under natural conditions. Of course, it is quite erroneous to say categorically that rain making is impossible, but this statement is not enough. Among the important unanswered questions are: Under what particular atmospheric conditions can rain be induced by artificial means? How frequently do such conditions occur, and what are the quantitative results; that is, how much rain can be produced artificially? These questions are vital to an evaluation of the practical possibilities of rain making as a means for materially augmenting the water supply.

There have been hundreds of reports of great success in seeding clouds and producing heavy showers. The evidence indicates that in most of the cases showers thought to have resulted from seeding were actually the result of natural causes. Much more research in cloud physics and mechanism of formation of precipitation

is necessary before the foregoing questions can be answered conclusively. The Weather Bureau has made hundreds of field tests and has published the results of observations. Many experimenters have reported only the rain-making tests which they have considered successful, and a factual picture of the possibilities has therefore been difficult to obtain.

F. W. REICHELDERFER, *Chief of Bureau.*

LIST OF PRINTED MATERIAL SUPPLIED BY THE WEATHER BUREAU AS EXHIBITS FOR THE COMMITTEE FILES

First Partial Report on the Artificial Production of Precipitation: Stratiform Clouds, Ohio, 1948. Research Paper No. 30, United States Department of Commerce, August 1948.

Second Partial Report on the Artificial Production of Precipitation: Cumuliform Clouds, Ohio, 1948. Research Paper No. 31, United States Department of Commerce, January 1949.

Artificial Production of Precipitation, Third Partial Report: Orographic Stratiform Clouds, California, 1949. Fourth Partial Report: Cumuliform Clouds, Gulf States, 1949. Research Paper No. 33, United States Department of Commerce, September 1949.

Evaluation of Results of Joint Air Force-Weather Bureau Cloud-Seeding Trials Conducted During Winter and Spring, 1949, Geophysical Research Papers No. 4, May 1950. Base Directorate for Geophysical Research, Air Force Cambridge Research Laboratories, Cambridge, Mass.

Reprints from Bulletin of the American Meteorological Society:

Volume 29, No. 5, May 1948, pages 266–269. First Partial Report on the Artificial Production of Precipitation: Stratiform Clouds, Ohio, 1948.

Volume 29, No. 10, December 1948, pages 544–546. Second Partial Report on the Artificial Production of Precipitation: Cumuliform Clouds, Ohio, 1948.

Volume 30, No. 7, September 1949, pages 255–256. Third Partial Report on Artificial Production of Precipitation: Orographic Stratiform Clouds, California, 1949.

Volume 30, No. 8, October 1949, pages 289–292. Fourth Partial Report on Artificial Production of Precipitation: Cumulus Clouds, Gulf States, 1949.

Reprinted from transactions of the New York Academy of Sciences, series II, volume 12, No. 8, June 1950: Section of Oceanography and Meteorology; Induced Precipitation and Experimental Meteorology; Importance of Artificial Nucleation for the Production of Precipitation; Large-Scale Control of Weather by Introduction of Sublimation Nuclei Into the Atmosphere.

Reprinted from Science, volume 113, No. 2929, February 16, 1951, pages 189–192: Dr. Langmuir's article on precipitation control.

Senator CORDON. How many of those seeding experiments such as were described by Senator Case has the Bureau engaged in?

Mr. MCDONALD. I repeat it here——

Senator CORDON. Let us find it.

Mr. MCDONALD. We ourselves made some 200 tests.

Senator CORDON. 200 tests?

Mr. MCDONALD. That is right.

Senator CORDON. Did you have or keep an account of the amount of silver iodide, if that was the chemical you used, that was seeded each time in given areas?

Mr. HALL. Sir, those were dry-ice experiments. The amounts were——

Senator CORDON. Let us stay with silver iodide. That was the one that was discussed here; was it not?

Senator CASE. We used the other.

Senator CORDON. All right, I want to remain with the one that was just mentioned. With dry ice, you had 2,000 experiments?

Mr. MCDONALD. No; 200.

Mr. HALL. Something less than 200.

Senator CORDON. What, quantitatively, was the number of times that after the seeding there was precipitation, and in how many was there not?

Mr. HALL. I will take 170 of those experiments which are the ones that were documented fully, and they are described here. Briefly, this is what happened.

Taking them altogether, Ohio, California, and Alabama, in 125 cases out of the 170 no precipitation reached the ground from seeded clouds. In 50 cases, a trace, which means a few drops, or one-hundredth of an inch, reached the ground. In two cases, eleven one-hundredths, a tenth of an inch, reached the ground. In 12 cases, a small shower appeared to reach the ground, although in those cases we did not use ground measuring. It was estimated from the airplane.

Senator ANDERSON. May I ask Mr. McDonald if the Weather Bureau has ever asked these local weather stations to report on rain-making activities in their own communities?

Mr. MCDONALD. Yes.

Senator ANDERSON. You have done that?

Mr. MCDONALD. Yes; we have done that.

Senator ANDERSON. They have reported on these?

Mr. HALL. Yes, sir.

Mr. MCDONALD. The reports are coming in; yes.

Senator HUNT. Mr. Chairman, I think we might arrive at some measure of the enthusiasm of the Weather Bureau for this program by having the budget officer make to us a statement progressively of your requests for this particular feature of your work, starting with 1949, and for 1950, 1951, and 1952. Have you each succeeding year asked for more money for this work, or what have been your requests?

(Subsequently supplied at a previous point in the record. See p. 22.)

Mr. MCDONALD. May I make, I think, a sound point?

In the business of asking for money, when you get thrown for a loss and an Appropriations Committee writes in a report a statement to the effect that they do not think the Government ought to be doing this kind of business, where does it leave us?

Senator HUNT. That is a well-taken point. What I am fishing for is to ascertain the measure——

Senator ANDERSON. Let me ask a question.

Mr. MCDONALD. I can answer very simply. The measure of our enthusiasm is not represented by these figures.

Senator ANDERSON. If the Appropriations Committee suggested to the Army not to build any more airships, do you think the Army would drop it right there?

Mr. MCDONALD. No; I do not think they would, but we have to pass a good many barriers on the way even to the Appropriations Committee, and such negative statements raise the hurdles; they do not lower them.

Senator CASE. Where do they begin, within the Department?

Mr. MCDONALD. Within the Department and at the Budget Bureau level.

Senator CORDON. I will suggest, Mr. Chairman, that the witness is on pretty sound ground there.

Senator ANDERSON. Thank you very much, Mr. McDonald.

Senator WATKINS. It is a good thing it is. He might not get what he is asking for in other fields.

Mr. McDONALD. Will that be all, Mr. Chairman?

Senator ANDERSON. That will be all.

(The following letter was subsequently received from Mr. F. W. Reichelderfer, Chief of the Weather Bureau:)

DELEGATION OF THE UNITED STATES OF AMERICA
TO THE WORLD METEOROLOGICAL ORGANIZATION,
Paris, April 7, 1951.

Hon. CLINTON P. ANDERSON,
United States Senate, Washington, D. C.

DEAR SENATOR ANDERSON: Recalling the interview in your office about March 1 on the problems of water supply, I would like to offer additional information in a short résumé of the work and views of the Weather Bureau with respect to rain making. An account of the March 14 hearings on S. 5, etc., just reached me here and the record would, I am sure, be incomplete if the following facts were overlooked.

Langmuir and Schaefer published the results of their first cloud nucleation in 1946. Recognizing the significance of their discovery in the study of cloud physics and rain formation, and in the development of experimental meteorology, the Weather Bureau, following their methods, carried on tests in the laboratory and in full-scale field experiments designed to determine the possibilities of artificial increase in rain-fall. During the next 2 years we made some 200 cloud-seeding tests. The results have been published impartially. Further, the Bureau kept closely in touch with tests conducted by other experimenters and for more than a year assigned a meteorologist experienced in cloud physics work to collaborate with Dr. Langmuir and keep the Bureau informed of progress. It is a matter of record that the Bureau not only eagerly welcomed the work of Langmuir and Schaefer but also repeatedly expressed its recognition of their discovery in official public statements. Our conclusions by 1949 were:

1. The economic possibilities of artificial rain making probably could be ascertained only by a more systematic and extensive research project. The Bureau immediately began work on plans for such a project and later proposed a suitable research program.

2. Although circumstantial evidence supported the reports of certain cases in which it was claimed that heavy rainfall had been produced, there was conclusive evidence that many of the claims were cases in which natural rainfall had been mistaken for artificial. (How easy it is to make this mistake was shown in one of the Weather Bureau's tests when our field staff initially were certain their cloud seeding had caused heavy rain but on careful analysis of radar-time records, the rain was discovered to have started before the seeding.)

3. The possibilities of drought relief, hurricane control, etc., by artificial means are still undetermined and not within immediate practical reach as the public had been led to believe.

If the Bureau's views have seemed negative or "unenthusiastic" it is only because the facts we have published spoke for themselves in terms which by comparison with the many exaggerated claims appeared conservative and because we have known that farmers were in many cases paying commercial rainmakers for rain which came naturally.

I can state with certainty that the Weather Bureau is enthusiastic about research to determine the possibilities of weather control and that its approach to this subject is open-minded and its desire is only to get the facts because they bear directly on many of the unsolved problems of meteorology and weather forecasting. The Bureau is experienced in this work, it has comprehensive plans for research and in cooperation with the best scientists in other interested agencies and research institutions, it is prepared to carry on the research promptly, effectively and economically. Examination of the Bureau's record of results per research dollar spent will show that its work in this field has been carried on at minimum cost.

The sessions of the World Meteorological Organization in Paris prevented me from appearing before your committee. Because of the bearing of this subject on the grave problems of water resources in some parts of the country, the Bureau is interested in doing everything possible at once to determine the possibilities for increasing rainfall. I am therefore sending this letter direct to you in the hope that it will reach you in time to be considered in connection with the pending legislation.

Sincerely yours,

F. W. REICHELDERFER,
Chief of Bureau.

Senator ANDERSON. Dr. C. G. Suits, who is vice president and director of research for the General Electric Co., will be heard next.

I think Dr. Vincent Schaefer and Dr. Vonnegut might just as well come forward and take chairs at the same time.

Dr. Suits, to start off, will you identify yourself and your position with General Electric?

STATEMENT OF C. G. SUITS, VICE PRESIDENT AND DIRECTOR OF RESEARCH, GENERAL ELECTRIC CO., SCHENECTADY, N. Y.; ACCOMPANIED BY VINCENT J. SCHAEFER AND BERNARD VONNEGUT, SCIENTISTS, GENERAL ELECTRIC RESEARCH LABORATORY

Mr. SUITS. I am vice president and director of research, General Electric Co.

Senator ANDERSON. And will you identify Dr. Vincent Schaefer?

Mr. SUITS. This is Dr. Vincent Schaefer, who is a scientist in our research laboratory, and Dr. Bernard Vonnegut, who is also a scientist in our research laboratory.

Senator ANDERSON. Can we help these people at the press table by asking whether or not Dr. Schaefer individually developed the cold box that started making clouds?

Mr. SUITS. Dr. Schaefer and Dr. Vonnegut, working in Dr. Langmuir's group, have pioneered the work in experimental meteorology, including the experiment you refer to.

Senator ANDERSON. And Dr. Vonnegut, did he do development in connection with the silver iodide?

Mr. SUITS. Dr. Vonnegut originated the silver-iodide method and did a very brilliant research in arriving at this fundamentally new method of nucleating cloud phenomena.

Senator ANDERSON. Does he have in his statement how many products he had to check before he got down to finding one?

Mr. SUITS. I do not think he does.

Senator ANDERSON. How many did you check, Dr. Vonnegut?

Dr. VONNEGUT. I personally have checked very few products. Schaefer has checked a great number and so have other investigators.

Senator ANDERSON. Did you not go through about 1,300 before you came down to 1?

Dr. VONNEGUT. What I did was to look in the handbook for a compound having a particular property, and there were 1,900 listed, and I just looked through the list until I found one that looked right. I did not try the 1,900. I just looked at them.

Senator ANDERSON. That is pretty good evidence you did not waste time. Proceed, Dr. Suits, if you will.

Mr. SUITS. I have a prepared statement, Senator Anderson, which I prefer to read, if you agree.

Few people would have considered seriously 10 years ago the possibility that the Congress would some day consider legislation for the control of weather, but that is one of the purposes for which this hearing is being held today. That advances in science may have a profound influence on man's way of life has been amply demonstrated by the explosive birth of the atomic age. An important aspect of the atomic energy development lies in the fact that man may release, or

in some cases control, a very large amount of energy. This is also an important aspect of the work on weather modification which we are considering. It is a fact that has been repeatedly demonstrated that under suitable circumstances one may with 1 pound of dry ice cause a thundercloud to precipitate a heavy rainstorm. In a typical case the energy of condensation which has been released is equivalent in magnitude to the energy of several atomic bombs. There are so many points of similarity between the release of atomic energy and the release of weather energy that it is well to consider them in detail. The similarities are—and I quote from a letter I wrote to you, Senator Anderson, dated November 22, 1950:

1. Large amounts of energy are involved. The energy release (in the form of heat or condensation) in a small thunderstorm equals the energy of several atomic bombs.
2. A chain reaction is an important basic mechanism in many meteorological phenomena and in atomic reactions. This permits a small initiating force to generate large-scale effects.
3. The national defense and the economic possibilities are vital aspects of both problems.
4. Both problems transcend State and National boundaries in their influence and importance, and ultimately will involve international agreements.
5. Extensive research is required to fully develop the economic and military applications of both forms of energy.

The dissimilarities in these problems should also be pointed out. They include:

1. Weather modification is in an earlier stage of development now than was atomic energy in 1946 when the Atomic Energy Act created the Atomic Energy Commission.
2. Huge plant and production facilities are not contemplated for weather modification and control.
3. There is no large body of secret process data in the present state of weather modification techniques. The fundamental methods are well known and do not require the employment of highly trained personnel for their use.

That is the end to the similarities and dissimilarities that I see in these two problems.

It seems to me that these comparisons between the character of the problems of atomic energy and weather energy are well recognized in S. 222 which is, I feel, a very thoughtful and important proposal for dealing with this matter.

It will certainly appear in the hearings on these bills that some of the scientific data are of a controversial nature. I think the hearings thus far have amply demonstrated that point. With natural phenomena which are variable as weather, this could hardly be otherwise. I would remind you, however, that there are many important scientific results of weather and especially cloud modification studies which are of very great potential importance, and which are not controversial at all.

I would like now to call upon Dr. Schaefer who will show some photographs of one particular experiment which it seems to me is completely proved by the photographs themselves.

Senator ANDERSON. Dr. Schaefer, would you mind moving to the end of the table so that all members of the committee will have a chance to see them?

Mr. SUITS. The particular experiment to which I refer is the experiment which has been accomplished repeatedly and consists in cutting a trough or a hole in a stratus cloud layer by seeding from

overhead with an airplane. The first photograph shows a seeding path which was produced by this method.

Dr. Schaefer, would you mention the dimensions there? What is the length of this track?

Mr. SCHAEFER. This track of which you see a portion is 30 miles long, and the circle is about a mile and a half across, and at this time, which I believe is 21 minutes after seeding, the width of the opening is about 1.2 miles, or something of that kind.

Mr. SUITS. Now, during this particular experiment, at a later date we have an additional photograph which shows the extent to which this seeded area has opened up and dissipated the cloud formation so that the ground could be seen through the continuous cloud deck. The photograph illustrates the same experiment. How long after the initial seeding was this taken?

Mr. SCHAEFER. This is about—I am guessing now—an hour and a half after. All of this data is in one of our reports, if anybody is interested in seeing it.

Mr. SUITS. Now, I mention this experiment because it seems to me there can be no serious controversy about it. The photographs demonstrate the result. It has been accomplished repeatedly. We think that the basic phenomena underlying the experiment are well understood.

Senator CORDON. What happened on the ground when the cloud was dissipated?

Mr. SUITS. What happened was that a small amount of snow fell. The amount of snow which can be produced from a cloud layer of this order—say, several thousand feet in thickness—is very small. It would perhaps amount to a few hundredths of an inch of precipitation; so, that snow has fallen, and you can see the changed character of the cloud which is the formation of snowflakes. They fall out.

They do not produce any great amount of snow from this kind of formation, but the principal result is the clearing of a cloud, so that in this case, for example, several hundred square miles of opening has been cut in the cloud deck.

Senator CORDON. In other words, the cloud was dissipated within an appropriate time after being seeded?

Mr. SUITS. That is right.

Mr. SCHAEFER. This is about 20 miles long and about 5 or 6 miles wide, and at the end of the experiment all of the internal region had transformed to snow and had fallen out, leaving a rectangular hole.

Mr. SUITS. This whole question of clearing holes in overcasts is of great importance.

Senator ANDERSON. It is militarily of great importance; is it not?

Mr. SUITS. That is right. Because of the pressure of so many things that must be done here, it has been given a very brief treatment. It deserves a great deal of further study.

Senator SMATHERS. May I ask a question right there?

Have the airlines, the commercial airlines, been interested in this sort of thing as a matter of making safe landings and things of that nature? Have they joined with you in any of your experiments on this?

Mr. SUITS. We have had some contacts with the airlines in this experimental work. I would prefer not to express the degree of their interest. I believe the military people have a substantial degree of interest in it.

Senator ANDERSON. Senator Smathers, United Air Lines' meteorologists are going to testify, I think tomorrow or the next day, with reference to it.

Senator SMATHERS. Fine.

Mr. SUITS. Now, if I may go on:

There is no doubt whatever that heavy local rainfall may be brougth about by seeding suitable cumulus clouds. The effect has been observed repeatedly in Project Cirrus experiments. Successful reports of such work have been made by scientists from many foreign countries as well as from many points in this country. It is a fact that much important weather phenomena, especially rainfall, is nucleated. That is, rain does not occur spontaneously throughout the entire cloud formation, but starts at one point and is propagated. It is an undisputed fact that most of the clouds seen in winter and nearly all of the high-altitude—above 12,000 to 14,000 feet—clouds in summer consist of water droplets which have not frozen although they are much below the freezing point of water in the bulk. Dr. Vincent Schaefer was the first to show how these naturally unstable clouds could be nucleated with dry ice in a historic experiment near Pittsfield, Mass., on November 13, 1946. Modern experimental meteorology was born on that day. For the first time in history, the old cliché about doing nothing about the weather had a new meaning. Dr. Bernard Vonnegut subsequently discovered a fundamentally different and very important method of cloud nucleation using silver iodide as the active agent. These experiments have a solid basis in much detailed scientific data which has accumulated in many years of work by scientists in our laboratory at Schenectady, and by civilian and military scientists of the Army, Navy, and Air Force working under Project Cirrus.

Senator CASE. With reference to the new meaning, Mr. Chairman, I think Senator Hunt's observation is much in point.

(See p. 11.)

Mr. SUITS. Very much.

Senator ANDERSON. Would you want to identify Project Cirrus?

Mr. SUITS. It has been referred to. It is the project under which this work is being done. The contracting is accomplished by the Signal Corps. The Office of Naval Research and the Army Air Force participate.

One other important fact should be mentioned here. For rainfall to occur, two conditions must be met. Here I wish to refer to some of the simple but very fundamental bases of this whole phenomena. First, the basic weather quantities such as temperature and moisture must be right; and, second, the nucleating agents must be present. It is an important fact of nature that the basic temperature and moisture conditions occur frequently in the absence of natural nuclei.

Senator CORDON. What are natural nuclei in this instance?

Mr. SUITS. The natural nuclei are very small particles, dust principally, which occur in the atmosphere at all times, and I will refer to them in somewhat more detail.

Dry ice and silver iodide are artificial cloud nucleating agents; they do not occur naturally in normal weather processes. Over a long period of time we have measured the natural nucleating agents, both in Schenectady, in New Mexico, and at the weather station on top of Mount Washington.

Senator CORDON. Is the weather station on the top of Mount Washington a United States Weather Bureau installation?

Mr. SUITS. I am not sure of that, Senator. I believe the Weather Bureau has work in progress there, but I think they, like we, are guests of the station.

Senator CORDON. Who owns the station and operates it?

Mr. SUITS. I think it has private auspices.

Mr. SHAEFER. That is correct. The Mount Washington Observatory is a private membership corporation sponsored by dollar memberships, and it is a small group that carries out basic studies in cloud physics, and has been since 1932.

Senator HUNT. What form of silver iodide is used?

Mr. SUITS. In the form of a very fine mist. None of these natural nucleating agents approaches the effectiveness of dry ice or silver iodide, and more important, their occurrence from time to time and from place to place varies by a factor of a million. In the southwestern part of our country it is frequently true that the sky is filled with clouds from which no rain falls, because of the practical absence of nuclei.

Senator CORDON. It would appear to me, in the Southwest, where we have the dust storms, there would be nuclei in abundance.

Mr. SUITS. That is true. During dust storms the nuclei count would be very large, but there are other times in summer when these tremendous cumulus clouds exist.

Senator CORDON. Why would we not have rainfall then along with dust storms?

Senator ANDERSON. We frequently do.

Mr. SUITS. I guess I will have to refer this question to the Senator who is much more familiar with New Mexico than I am.

Senator CASE. Mr. Chairman, is it not frequently a common observation when these dark clouds come up even during periods of drought and no rain comes, the common expression is, "Well, the rain went around," and perhaps that might have been the absence of nuclei to make the cloud let loose its moisture?

Mr. SUITS. That certainly is a clear possibility. It is in such circumstances that artificial nucleation is particularly effective.

These facts which underlie experimental meteorology are not in the controversial area; they have been demonstrated and proven. What controversy has arisen has been concerned with such matters as (1) the economic importance of induced rainfall—by "induced rainfall" I mean artificially induced rainfall—(2) whether long-range effects of cloud seeding exist, and (3) whether induced rainfall may not have occurred naturally in the absence of seeding. There is a great mass of information bearing on these questions, and it would not be possible to discuss it all here. It is my considered opinion, however, that the results of most recent work are of the very greatest importance to the Nation. We have at hand a means of exerting a very considerable degree of control of weather phenomena. Precisely how much control can be accomplished will come from further study. Much work remains to be done and it would be a national tragedy if legislation did not provide a proper framework for developing the full potentialities of weather modification methods. It would be hard to imagine anything more important to the country than weather modification and control. It cannot be said that this result is assured by any means; but the results to date give great promise in this direction.

As you probably know, Dr. Irving Langmuir has been in charge of this work at our laboratory in Schenectady; Dr. Schaefer and Dr. Vonnegut are his principal scientific associates in the work.

Dr. Irving Langmuir is one of the world's outstanding scientists primarily because of his extraordinary insight and understanding of natural phenomena. He has at many points in his remarkable career found himself in the midst of scientific controversy. I think this has often been so because of the fact that he can so quickly see and understand things in nature which seem puzzling to others. I will not deny that he also loves a good fight, and in the present controversy he is having the time of his life. I do not recall that he has ever lost a scientific argument and I don't expect him to lose this one.

Senator CORDON. May I go back to nuclei for a minute? I come from the State of Oregon, in the western portion of which rainfall is not uncommon, and it is most common in the very western part of western Oregon where the average precipitation in some places reaches around 100 inches a year.

If there are any dust particles, I do not know where they would come from. Can we say that one of the nuclei would be the meeting of a water-bearing cloud with a sharp change in temperature?

Mr. SUITS. No, I think not. I believe it is true—and Dr. Schaefer and Dr. Vonnegut can give more detail on this—that we have never found a condition which showed no nuclei in the atmosphere.

Senator CORDON. You would have to find something besides the dust.

Mr. SUITS. You realize this dust may come across the Pacific. Volcanic dust has been known to circle the earth many times and airborne dust particles are always present. They vary from, let us say, 5 or 6 or 7 per cubic meter, which is somewhere near the minimum, to roughly 1,000,000 times that.

Dr. Schaefer has undertaken an extensive test of how effective are these airborne natural particles in terms of nucleating clouds, and these results have been published and they show that they vary all the way from extremely ineffective nuclei to nuclei that are perhaps 10 or 15 times less effective than silver iodide. Silver iodide is an unnatural substance.

Senator CORDON. I consider that western Oregon is an exception to your rule, but we will wait and see what develops.

Senator CASE. You would not want the impression to remain that dust of itself is an essential or even perhaps the most common nuclei that might result in rainfall?

Mr. SUITS. I do not believe these particles should be properly referred to as dust.

Senator CORDON. That was your reference.

Mr. SUITS. Yes; that is right. The particles that cause this phenomena which we measure, we do not analyze they are so tiny. They are simply particles which cause nucleation. Now, the tests that Vincent Schaefer has made that I referred to were cases where he has taken actual dust, he has taken volcanic dust from various parts of the country and has used this as the nucleating agent in laboratory experiments, and there is a simple means of putting an index on each of these kinds of materials as its effective for nucleation. Would you care to elaborate on that?

Mr. SCHAEFER. Yes; I will be very glad to. For example, in Oregon, if you take the old volcanic ash from Crater Lake, it has a threshold of activity of about minus 18°.

Mr. SUITS. Do you want to explain what that means?

Senator CORDON. You mean it will not work?

Mr. SCHAEFER. Not until you get to a temperature of minus 18°, and then it begins to become a fairly effective nucleus.

Senator HUNT. Will you explain the reaction in terms of either physical or chemical reaction?

Mr. SCHAEFER. I cannot say we really understand it. What we know is when we dust these very small floating particles in the chamber, there is a period of incubation, you might call it, of about 30 seconds during which time presumably a single layer or more of water molecules are depositing out on certain surfaces of these particles.

Once that layer is there, then for all intents and purposes we have an ice crystal and it then continues to grow like any other ice crystal grows, by the water molecules leaving the water droplets and through the vapor phase, that is, by evaporating from the water drops the molecules condense on the ice crystal because of the greater tendency for water to evaporate than for ice to evaporate. Therefore, it is a one-way movement of the moisture from one particle to the other.

Now, there are some particles, certain spores which are not active until you get to a temperature of minus 35°, but I think one of the most important factors of nucleation is the cirrus cloud settling down from high altitude and invading some of our lower clouds and setting them off.

Senator HUNT. That is sort of a process of capillary attraction, then, is it not?

Mr. SCHAEFER. Well, as far as we believe the reason the cirrus clouds work as readily as they do is because they are so very cold that they spontaneously shift over to ice crystals. They are at a temperature minus 39° as a rule, and we find if we take a chamber and introduce moisture in it, we cannot do that below 39°. They shift over to ice at that temperature. It turns out many, if not all, of the cirrus clouds that we have studied have been colder than minus 39°.

We have flown up into them, and as a rule they are between minus 40° and minus 45° where the incipient growths occur, and then they gradually grow and settle down.

Senator CASE. Mr. Chairman, the reason that I tried to find out whether we were confused in talking about dust, is because when the layman thinks of dust he thinks of a dust storm or something of that sort, and in the current number of the Country Gentleman for March 1951, Dr. Vonnegut is the authority for the author's referring to a small silver-iodide generator which could be fitted comfortably in the palm of the writer's hand, and then he says:

> One such tiny generator fed with burning gas and silver iodide sends up one quadrillion particles of silver iodide per second. Each particle is enough under proper conditions to make one snowflake or raindrop.

I do not know whether he wants to elaborate on that here, but in one second if one quadrillion particles can go up out of something that can be held in your hand, it puts a new interpretation on the layman's idea of dust.

Senator ANDERSON. I think it is very useful that that question was cleared up because some might think it was just street dust.

Mr. SUITS. If I may go on, Senator Anderson, about Dr. Langmuir. I will remind you of a few of his accomplishments. His discovery of the role of gas in the incandescent lamp doubled the efficiency of this lamp and saves the American public a billion dollars a year in electric-light bills. His development of the high-vacuum-power tube gave radio broadcasting and receiving its greatest single impetus. His atomic hydrogen welding first made possible the welding of aluminum, stainless steels, and refractory alloys. His studies of the mercury discharge led to the development, with Dr. A. W. Hull, of industrial electronics. His studies of electron emission are classics of science and have had multiple applications in the electronics industries. He opened a new branch of science known as surface chemistry which placed a whole new set of tools in the hands of the biochemist. The mercury diffusion pump which he developed has been vital to the practical industrial use of high vacuums.

The most important of many developments he made during World War II was the smoke generator, which in fact was important in leading to this line of experimentation. From first scientific principles he conceived screening smokes which were thousands of times more effective than any in use in our Armed Forces up to that time. They played an important military role in the Pacific and in Europe, especially during the crossing of the Rhine.

He has been the recipient of dozens of medals from the principal scientific societies of the world. He was the first American industrial scientist to receive the Nobel prize. Langmuir is a versatile scientist, and when he is among chemists, chemists claim that he is one of the world's greatest chemists. Physicists call him one of the world's outstanding physicists. Some day meteorologists will undoubtedly recognize a new science of experimental meteorology which he and his associates have founded. As I mentioned earlier, if Langmuir loses the scientific argument which he is now enjoying, it will be his first loss. I will place my bets on Langmuir.

I wish to be very clear on one point. The work which my company has done in this field, initially at our own expense, and more recently under a Signal Corps contract with the participation of the Office of Naval Research and the United States Air Force, has had no single practical application within the company. The work originated as an unexpected result of one of the many fundamental investigations which we undertake in the search for new knowledge. It was continued because the leaders of my company and responsible representatives of the Government believed that the possibilities of weather modifications might be of great importance to the Nation as a whole. On December 27, 1950, my company announced that for the present and until further notice it does not intend to enforce any of its patents relating to weather modification by the artificial production of snow and rain.

A contractor of the Government for research in this field, where the general public is the intended beneficiary, should not be subjected to the uncertainties of legal liability hazards which are inherent in experimental weather modification. The provisions of S. 222 would greatly minimize the legal hazards which now exist. Some such solution of this problem must be found if private agencies are to engage in research in this field, and by that I mean under contract with the Government.

The facts which I have presented and the testimony which my associates, Drs. Schaefer and Vonnegut, are about to present will, I believe, demonstrate persuasively that Senator Anderson's proposed legislation would be of substantial benefit to our country.

Senator ANDERSON. Do you want Dr. Schaefer to proceed now?

Mr. SUITS. If you please.

STATEMENT OF DR. VINCENT J. SCHAEFER, SCIENTIST, GENERAL ELECTRIC RESEARCH LABORATORY, SCHENECTADY, N. Y.

Mr. SCHAEFER. With the permission of the committee, I would like to read mine, too. It will probably save time.

Since November 1946 when our first experimental studies concerned with the modification of supercooled clouds in the atmosphere were inaugurated in the northeastern United States, much effort has been directed toward reaching a better understanding of the physical and chemical relationships which exist between water vapor, cloud droplets, temperature, and the various types of nuclei existing in the atmosphere.

The results obtained in the first five flights made in 1946 were so promising that negotiations were opened with the United States Army Signal Corps and the Office of Naval Research for the establishment of a basic research study concerned with the processes leading to the formation of snow and rain in the atmosphere.

These efforts resulted in the establishment of Project Cirrus: a joint project of the Signal Corps, the United States Navy, and the United States Air Force. Funds, equipment, and personnel were supplied by the Signal Corps and the Navy. Aircraft with appropriate air personnel were supplied by the United States Air Force and the Navy. The Weather Bureau has cooperated with personnel and weather data. Since 1946 the General Electric Co. through its research laboratory has concentrated its efforts in weather modification in laboratory experiments and toward supplying consultants and observers with the required scientific background.

During the period of March 1947 to August 1950 a total of 174 flights were made in the northeastern United States, as well as short period investigations in the vicinity of Florida, Puerto Rico, and New Mexico. For the majority of flight operations one or two B–17 aircraft were employed which contained special instruments for obtaining detailed information with respect to atmospheric conditions. In addition, a number of instruments and devices were designed and constructed by our group for conducting specialized studies.

Flight operations were planned insofar as possible in the manner of basic laboratory experiments. The experiences of past flights were utilized to uncover new phenomena and, at the same time, to run checks on the results of the past. For this reason, few of the flights duplicated previous operations.

Flights concerned with cloud modifications were planned on a small scale so that the results of seeding operations would be localized, thus permitting comparisons between affected and unaffected areas.

In addition to the flight operations, many laboratories and field studies have been conducted as part of Project Cirrus. These have included studies of all kinds of nuclei, the physical relationships existing in natural rain and snowstorms, the rate of growth of snow

crystals and raindrops, the growth, formation, and dissipation of various types of clouds, methods for making measurements of the particle size, size distribution, and liquid water content of natural clouds, and the factors which govern the structure of snow crystals.

The experimental studies using aircraft for seeding stratus and cumulus clouds have always shown positive reactions whenever supercooled clouds were present. The observed effects have ranged from converting stratus clouds into areas of tiny snow crystals to the development of heavy local rainstorms in large cumulus clouds. As might be expected, the varied results were directly related to the vertical thickness, moisture, and turbulence in the clouds affected and the stability of the atmosphere in which they formed.

The most striking results were obtained in New Mexico where the introduction of small quantities of dry ice fragments—1 to 2 pounds per mile of flight—into groups of cumulus clouds led to the formation of heavy rains in the seeded areas. The precipitation areas as observed by radar and by ground and plane observers exactly coincided with the places where seeding took place. The rains generally started within 20 minutes after seeding and lasted for from 2 to 5 hours afterward, producing substantial quantities of water on the ground and in the drainage streams.

These and other studies have been described in a series of 28 occasional reports and 23 scientific papers which have been published to date. A considerable number of additional reports and papers will be published in the near future.

On the basis of the results of the flight operations and the laboratory and field studies, it is obvious to me that further activities in this field justify an increased activity on the part of the Federal Government, both in exploratory basic research, as well as a well-formulated program designed to apply and evaluate the discoveries in this field which are the basis of our present knowledge.

Despite our difficulty in defining the very complex interrelationships which exist in the atmosphere between air, pressure, radiation, moisture, and suspended particles, the reactions which occur are, in general, physical and chemical in nature and, therefore, should be susceptible to an eventual understanding. As in any of the experimental sciences, unstable conditions occur which, if properly recognized and exploited, may be forced to yield results of a very specific nature. It is of the utmost importance that a broad study be made to establish the nature and degree of these instabilities and of the possible reaction which may be initiated by trigger actions and other mechanisms which may be quite minor in their magnitude but lead to major reactions as they run their course.

Since the movement of storms and other weather phenomena show no respect for State or even national boundaries, it seems reasonable to anticipate that the Federal Government should concern itself through Congress with the establishment of a commission to institute a broad program of basic and applied research toward reaching a better understanding and utilization of weather processes. Such activities may lead to results conducive to the advancement of the economic welfare of our Nation through the better utilization and conservation of atmospheric moisture, as well as the prevention or moderation of the intense storms such as produce torrential rain, lightning, hail, and high winds.

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Our studies show that great variabilities occur in the concentration of ice crystal nuclei in the atmosphere. These variations cover a range of at least a millionfold and are probably directly related to the great difficulty which weather forecasters encounter when they attempt to predict icing hazards for aircraft due to supercooled clouds. This variation in ice nuclei is probably intimately related to the sudden development of intense storms, including thunderstorms, hail, and tornadoes, since such types of storms develop in areas which favor the development of large vertical thicknesses of supercooled clouds. As is well known, such storms are also difficult to forecast except in general terms.

If such factors were not of common experience, it would be foolish, indeed, to urge that an intensified research and development program be sponsored by the Federal Government. Since it is possible to modify supercooled clouds on an extensive scale and to equal or even exceed the natural supply of ice crystal nuclei in the atmosphere, it seems reasonable to expect that a Federal program of research and application is justified at this time.

It is very important, in my opinion, that weather studies involving experimental meteorology be conducted in such a manner that all of the modifications attempted by man-conducted seeding operations be known and controlled. If this is not done, the effort of attempting to understand the reactions which occur is a hopeless one. Whether such operations can be conducted by licensing the private groups now in this field and soliciting their active cooperation or whether it will be necessary to attempt the exercise of complete control over such seeding activities is a problem which must be solved in the near future. I believe that the former procedure—licensing of private groups—is to be preferred if at all possible.

It is obvious that some type of national legislation is of the utmost importance at this time to protect the public in the future from unscrupulous individuals who would play on the gullibility, hope, or desperation of individuals or groups in need of water or other relief from an undesirable climatic situation. It is important that the efforts of some of our best scientiests interested in the many complex relationships existing in weather phenomena be directe ' toward determining the facts and properly informing the general public of their findings.

I believe that an intelligent, scientific, and well-planned program of research and application approached with enthusiasm and using presently known techniques, but geared to exploit new ones that would flow from the proper kind of basic studies, would certainly be worth the effort which will be required to initiate and establish such an activity for the national defense and eventual welfare of ourselves, as well as the other peoples of the world.

Senator CORDON. Mr. Chairman, I have one question to ask. Up to now has there been any consideration given to the very opposite of inducing this nuclear reaction; in other words, of putting an end to it?

Mr. SCHAEFER. You mean preventing rain?

Senator CORDON. Well, of reducing rain here and stopping it there.

Mr. SCHAEFER. Of course, we have thought about it, but I do not think we are in any position to say yes or no. I think that is the kind of thing that has to be decided by a very competent group who will carry out controlled experiments.

Senator CORDON. This sort of study is within the realm of possibility?

Mr. SCHAEFER. It seems to me reasonable from what we know now.

Mr. SUITS. I think it is in the realm of hope. Very little work has been done on that subject.

Senator SMATHERS. Mr. Chairman, have not experiments been conducted in attempting to dissipate hurricanes? It seems to me I recall down off Puerto Rico, about a year or so ago, the Air Forces from Orlando, in conjunction with scientists, attempted to break up a hurricane heading toward Florida, and, I might add, without success.

Mr. SCHAEFER. First of all, I would like to correct a misconception here. I was on that flight, and the main reason we made the flight was to see what a hurricane was made up of on top. With their supercooled clouds, how many supercooled clouds were there; could those clouds be changed? We did not try to break up the hurricane.

Senator ANDERSON. It was not headed toward Florida but away from Florida, was it not?

Senator SMATHERS. It was unusual if it was.

Senator ANDERSON. It was headed toward Florida and decided to go to Bermuda.

Mr. SCHAEFER. This was primarily directed to finding out about young hurricanes. We set up several dry runs and were all set to study small hurricanes. As always happens, the weather did not cooperate and not until October did a hurricane form that looked like it might be something we could do basic studies on.

We alerted our groups and went to Florida but found that by the time we got there, which was within 48 hours, the hurricane was already over Miami. We then decided to wait until it was three or four hundred miles at sea to then go out, make the studies that we are interested in, and carry out a localized seeding, which we did. That is about all that happened. We took many pictures, made many temperature altitude studies and came back to base.

Senator SMATHERS. You say you carried out some localized seedings on that hurricane after it passed over Miami. What were the results?

Mr. SCHAEFER. We do not know.

Senator SMATHERS. You do not know what the results were. I hope you will try it again.

Mr. SCHAEFER. I hope so, Senator.

Mr. SUITS. I think it should be stated, Senator, that studies of hurricanes ought to be a part of future research in this area. Hurricanes may be susceptible to control.

The fact that it is such a hazardous operation not from the standpoint of doing the experiments but from the standpoint that public liability now stands in the way of such work. I think this question points particularly to the wisdom of the liability provisions of S. 222. Here is a case where there is the potential possibility of incurring tremendous liability. No one is willing to do that under present laws.

Senator ANDERSON. Dr. Suits, was it not true that the hurricane, if it subsequently turned back toward the United States and it had destroyed property, it might have been a very expensive procedure for General Electric?

Mr. SUITS. That is right.

Mr. SCHAEFER. It so happens that we did not conduct the experiments, but nevertheless I concur in the need for much further studies of this very important problem.

Senator SMATHERS. Certainly a hurricane which creates as much damage as the hurricanes do to Florida, and all over the country for that matter, would seem to me to be a matter well worth study to see if they cannot be eliminated or controlled in some manner.

Mr. SUITS. That is right.

Mr. SCHAEFER. It should be pointed out, of course, that the Weather Bureau is doing a very good job right now in making certain kinds of studies of these. We think they should be greatly supplemented and perhaps a very special project set up to do nothing but have that as its assigned purpose to get the basic information as to supercooling, nuclei, and everything else that ties in with the thing that makes the hurricane go.

Senator CASE. I might interject, if I may, there, Mr. Chairman, that the public interest that attaches itself to the possible damage from a hurricane also attaches to the potential benefits and the control of forest fires.

Senator ANDERSON. Right. Dr. Schaefer, is it not possible also by your pattern of seeding to dissipate a severe storm that might tear up the landscape?

Mr. SCHAEFER. Our fond hope is that a suitable study can be made to determine whether or not regions which, for example, like the Northwest, Idaho, and Oregon, where they have many lightning fires, whether it should not be possible where you have localized thunderstorm development—and there are many places in the West which are just like that, little mountains are the generators of the thunderstorms—to work on the clouds as soon as they form, as soon as they reach the freezing level or slightly above and just continually dissipate them as fast as they grow.

Now, it might happen that silver iodide is the best way to do that from the ground, but it involves a very thorough knowledge as to where the air goes from as it leaves the ground, where the moisture comes from that goes into the clouds, because that is where you have to put your generators.

Senator ANDERSON. Did I understand you to say that the Weather Bureau had done a very excellent piece of work on hurricanes?

Mr. SCHAEFER. Their hurricane-warning system is excellent.

Senator ANDERSON. And you recommend additional money for them?

Mr. SCHAEFER. I am not sure that that is the best way to do it. I am just throwing that open as something that needs a great deal of attention and perhaps they are the best ones to do it. I should mention that this kind of information requires aircraft specially instrumented, capable of flying at high altitudes for getting the kind of information necessary, and they need to be equipped with the best of equipment for getting specialized information.

Senator ANDERSON. May I ask two short questions here. Have you brought along the film that shows what happens when you seed a cloud?

Mr. SCHAEFER. I am sorry, Senator, I have not, but I intend to be here Monday, and if the committee would like to see it——

Senator ANDERSON. The committee would like to see the film. Would you bring it down?

Mr. SCHAEFER. I will be very glad to.

Senator ANDERSON. Would you also say whether you have had to develop any particular types of instrument to use in airplanes as a result of this?

Mr. SCHAEFER. I think Dr. Vonnegut is in a much better position than I am to answer that.

Senator ANDERSON. Dr. Vonnegut, may we have your statement now? We can ask additional questions later.

STATEMENT OF DR. BERNARD VONNEGUT, SCIENTIST, GENERAL ELECTRIC RESEARCH LABORATORY, SCHENECTADY, N. Y.

Mr. VONNEGUT. With your permission, Mr. Chairman, I would like to read my statement. I would like to say first that this statement expresses the way I feel concerning the necessity for Federal legislation concerning cloud seeding, and represents convictions that I have on the basis of experiments that I have witnessed in the outdoors and have conducted in the laboratory.

I am convinced that by the use of cloud-seeding techniques it will be possible to exercise a considerable control over the weather for the general good of our country.

Experiments which have been carried out by "Project Cirrus," and by other groups in this country and in many parts of the world make me confident that the following benefits can be achieved by the wise use of cloud seeding:

1. Control over the weather to increase precipitation where it is needed and to reduce it where it is not needed.
2. Reduction of the frequency and severity of damaging storms and floods.
3. Reduction of aviation hazards, such as icing conditions and conditions of poor visibility.
4. Reduction of hail and its large damage to agriculture.
5. Increasing the accuracy of weather forecasting.

Despite a strong personal dislike of restrictions and regulations, I am also convinced that in order to achieve these benefits, cloud seeding must be placed under strict Federal regulation.

The problems of weather control are so large and of such Nation-wide importance that only Federal legislation can insure that this powerful new tool will result in the greatest good for the largest number of people. In the absence of this legislation, I believe that the development of the benefits to be derived from cloud seeding may be greatly retarded or prevented and that possibly much harm can result from storms, droughts, or floods produced by uncontrolled seeding.

Theory has predicted and experiments are confirming the fact that a few pounds of silver iodide released into the atmosphere in the form of fine particles can exercise a profound influence over the weather hundreds of miles away from the point of release. Clearly no private individual or group can be permitted to carry on operations likely to affect weather conditions over thousands or hundreds of thousands of square miles.

The potentialities, both for good and bad, which attend silver iodide seeding are so large that the development and use of this technique must be placed in the hands of the Federal Government.

Secondly, it is highly desirable that the Government pass laws regulating cloud seeding in order to promote the rapid development of this science. Many facts are yet to be learned concerning the best methods of seeding to obtain desirable results. These facts can be determined only by experiments in the atmosphere. The analysis of the results of cloud-seeding experiments is a complicated and difficult problem. If, as is the case at present, many seeding experiments are being independently and simultaneously carried out in many places the problem of analysis becomes even more difficult and frequently impossible. Federal regulation is necessary to insure the rapid development of the benefits of cloud seeding.

Thirdly, the science of weather control can be of such great benefit to the entire country that the responsibility for its advancement must rest with the Government. Legislation should provide funds for research by Government and by private groups into fundamental scientific problems connected with the weather.

Because silver iodide seeding can have very widespread and persistent effects, I believe that use of this technique should be confined to the Government. On the other hand, seeding with dry ice should be generally permitted under license. Seeding operations carried out from an airplane with dry ice are not likely to produce the very widespread effects produced by silver iodide, and the precipitation produced can be more easily confined to the smaller areas which are the legitimate concern of private groups. It is important to the development of the science that all groups carrying out seeding should conduct their work in a scientific manner. The experience gained in this work should be published and freely shared with other workers to the advantage of all. The free exchange of scientific knowledge which characterized the early work on cloud seeding has greatly aided the rapid development of this new science. The continuation of this free exchange of information is vital to the full development of its possibilities.

Senator ANDERSON. May I stop you right there, Doctor. You suggested silver iodide might be confined to the Government and seeding with dry ice permitted under license. One of these rainmaking organizations has one of its salesmen out telling farmers that they use silver iodide and that only affects a very narrow, limited area, but that dry ice will affect conditions thousands of miles away and therefore they do not use dry ice. Would you comment on that?

Mr. VONNEGUT. Yes. I would say that from all of our work on this, that the situation is pretty much the reverse, I would say that from a scientific point of view. When you seed with dry ice you generate small ice crystals in a cloud. That is what seeding is. The ice crystals which are generated by the dry ice will grow if they are in a cloud.

If the cloud should dry up or warm up, the ice crystals will evaporate or melt and they will cause no effect other than in the particular cloud system in which they were introduced.

Silver iodide seeding, on the other hand, is seeding with a substance which produces ice crystals when it gets into a cloud. The silver iodide is fairly persistent in the atmosphere. It does not melt, it does

not evaporate, and, if it does not work where you put it into a cloud, it may work a long distance away. It can survive, so that we feel it can be a very general effect.

Senator CORDON. You do not agree, then, with the statement made earlier here that silver iodide loses its potency within a half hour if released in the sunlight?

Mr. VONNEGUT. Quantitatively, I do not agree with that statement. I think the forthcoming issue of the bulletin of the Meteorological Society, the group at the New Mexico School of Mines and your group have published a paper on just this subject. We find in our experiments that after exposure to the intense New Mexico sunlight, silver iodide smokes drop to about one-tenth of their effectiveness at the end of 1 hour. If the smoke goes under a cloud, it is protected from the ultraviolet radiation and would exist for much longer periods of time.

Senator ANDERSON. Therefore, your comment is based on actual experimentation of your own?

Mr. VONNEGUT. That is right.

Senator CASE. Use of the dry ice is more likely to be on a local cloud, is it not?

Mr. VONNEGUT. That is right.

Senator CASE. And you are more likely to get local effects?

Mr. VONNEGUT. That is right. Dry ice has to be used from an airplane. It has to be introduced into a particular cloud. In the silver iodide method, you make smoke on the ground and hope it goes up into the cloud that is going to produce effects over your area.

Senator CASE. In our very limited experiments that, of course, is what we were trying to do. When the boys went up they simply took the cloud that was nearest them or that was near the area that they wanted to work on, and worked on that particular cloud, and the results were quite local.

Mr. VONNEGUT. That is right. It is much easier to evaluate because when you seed with dry ice you put it into a cloud and you know you seeded a particular cloud.

When you are generating silver iodide that is invisible smoke on the ground, you can have an awful lot of trouble figuring out just where it is going. It is completely invisible. Eventually it will be possible to trace it better than we can now, but it is a tough job.

Senator CORDON. How long life does it have, that is for its potency in the air?

Mr. VONNEGUT. It depends a great deal on what the conditions are.

Senator CORDON. Take a complete cloud overcast.

Mr. VONNEGUT. I think if the silver iodide is under a cloud, our experiments indicate that it possesses its effectiveness indefinitely. It is a difficult problem to simulate in every way the experiments in the natural atmosphere, in the laboratory. The only way that we are going to get answers to this problem of how long silver iodide lasts in the atmosphere is by making flights with the new instruments for measuring how much silver iodide is there, how many effective nuclei there are.

Senator CORDON. Do you have any such instruments now?

Mr. VONNEGUT. We have such instruments under development.

Senator ANDERSON. I was going to ask you, Dr. Vonnegut, if in this paper you comment on those, or, if you do not, would you comment now on some of the developments, some of the devices that you have had to develop.

Mr. VONNEGUT. I think you can appreciate that in a new science or a new branch of science such as we are dealing with here, that you need new equipment. You have to measure things which have never been measured before or you have to measure things which have been measured before much more accurately. A large part of our program has been the development of new instrumentation both for use on the ground and in the airplane.

I might mention, for example, instruments such as a device for automatically measuring the number of ice-forming nuclei in the atmosphere, those occurring naturally, and those which we produce. We are also making continuous measurements with a new device of the number of condensation nuclei in the atmosphere. I might say the condensation nuclei are much more prevalent in the atmosphere. That is the sort of foreign particle around which the cloud drops form.

We think that the concentration of these nuclei must indeed be related to the course of the weather, and we are measuring it. We have a lot of data. We do not know too much what it means, but we hope when we get enough of it we may be able to generalize it.

Senator HUNT. Doctor, you of course are primarily interested in the scientific aspects of this subject, but should we not now, possibly even before we have established too much scientific knowledge, start doing some work on legislation with reference to the ownership of moisture above the ground, whether it belongs to the State, whether it belongs to the Nation—who it does belong to?

Mr. VONNEGUT. Well, I think that I am a poor one to ask a question like that because my training is primarily scientific and I would not venture a legal opinion.

Senator HUNT. I mention that at this time, Mr. Chairman, because the clerk has just handed me a telegram from Earl Lloyd, deputy State engineer, Cheyenne, Wyo. Our legislature has just adjourned and the telegram reads:

> Your wire Wyoming Secretary of State relative action Wyoming Legislature on "rain making" referred to this office. Thirty-first Wyoming Legislature enacted senate file 61, now chapter 131, Session Laws of Wyoming, 1951, which declares claim of State of Wyoming to sovereignty to its atmospheric moisture, creates a State Weather Modification Board, and sets out purpose: To promote weather modification experiments, provide for accumulation and evaluation of data relative to such experiments, and to protect life, property, and public interest from injurious practices.

I might say I know the gentleman who introduced the bill. He lives near the South Dakota line, and last year South Dakota had some very profitable experiments in rain making. We think they stole some of our water, maybe.

Senator CASE. I might say that the prevailing winds, though, are generally from the northwest.

Senator ANDERSON. I am very glad this telegram came up because it illustrates precisely the point that I had in the discussion of this. We are shortly going to have to have policemen up in the skies policing them to see that some State does not steal some other State's weather, if you do not get Federal control over this problem.

It is not as humorous as it may seem, because I have in front of me a map which shows the water condition in the headwaters of the Rio Grande, and there is not a place there where it is above 60 percent of normal, the snow is 40, 45, 50, 40, 55, 65, 65, 60, and then in another area where there has been some seeding it runs up to 110, 160, 170.

Now quite obviously the thing for the State of New Mexico to do is wait until the clouds are forming in Colorado and the direction of the wind is down toward us, and then go up and introduce just enough silver iodide to overseed there and take a chance that we will get it in our watershed, and just as it is about to drop here, then I suppose Arizona should come over and hope it goes in their direction, and all we can do is to destroy the whole weather pattern of the United States if this thing is done indiscriminately, and produce drought everywhere instead of drought in spots. Whereas, if there is some planned and patterned program, I think it is possible to produce additional rainfall all over the United States, and I would like to go back to that question and ask that, if I may.

Dr. Suits, do you agree that it is possible to increase, or might be possible—I do not want to commit ourselves definitely that it is, but is there hope—that we could increase rainfall in areas that are now arid without interfering with normal rainfall elsewhere?

Mr. SUITS. I think this is certainly a question that will deserve a great deal of further study, but this can be said. Of some studies which have been made, it is clear that of the moisture which falls in a given area, let us say the eastern part of the United States, that is a very small fraction of the total moisture available in the upper atmosphere.

In other words, the upper atmosphere is a reservoir from which we are now tapping a small portion, and it seems to me that basically that gives the hope that increased rainfall can be produced. I think a detailed answer really should not be attempted.

Senator CORDON. May I suggest, Mr. Chairman—and I fully agree with the statement you just made, but may I carry it one step further and suggest—that after you have done that seeding in Colorado and New Mexico, you may get a little message from the Government of Mexico indicating that that seeding has been an unfriendly act so far as Mexico is concerned.

Senator ANDERSON. May I just pause to say the point is that here is a State, Wyoming, trying properly and vigorously to control its own atmosphere and other States will try to do the same thing.

When we realize that countries outside of our territorial limits can completely alter it and these individual States cannot contract with Mexico and cannot contract with Canada, it requires the legal force of the Federal Government in order to make these experiments possible, because only the Federal Government can range in those areas where it is necessary to work.

Senator SMATHERS. Certainly it is not just a State problem or the Federal Government's problem. You have Mexico to contend with and Canada, Cuba, Nassau, which is controlled by Great Britain, and these clouds flowing back and forth over all these nations, as it were, require, it seems to me, if we get into a legislative field, we are going to have some international law in addition to a lot of Federal law. There will be many bureaus, boards and agencies.

Senator ANDERSON. May I put into the record at this place a statement from Jack McFall, Assistant Secretary of State, to Senator Edwin Johnson, chairman of the Committee on Interstate and Foreign Commerce, with reference to that necessity of having international transactions.

(The letter above referred to will be found on page 31.)

Senator CASE. Mr. Chairman, the point you made is certainly clear, but we ought not to lose sight of the point made by Dr. Vonnegut in his basic statement which precipitated this; that is, he drew a distinction between the use of silver iodide and the use of dry ice, and I would like to repeat his sentences if I may just for the purpose of emphasis so we do not lose the point he sought to make, and I quote:

> Because silver iodide seeding can have very widespread and persistent effect, I believe that use of this technique should be confined to the Government. On the other hand, seeding with dry ice should be generally permitted under license.

I think that we ought not to lose sight of that point.

Senator ANDERSON. I am glad you brought that out, Senator Case, because all over this country there have been associations and farmer groups and so forth that have used seeding with dry ice, and I think that nearly everyone will concede that they are not robbing any other State of moisture, that they are helping to precipitate rain in their own locality, and that that is something quite different from this possibility of silver iodide generators which might have an effect would you say, a thousand miles away or 2,000 miles away?

Mr. VONNEGUT. I think it is conceivable, yes.

Senator ANDERSON. It is entirely possible, is it not, 2,000 miles away?

Mr. VONNEGUT. That is right.

Senator ANDERSON. Will you proceed, Doctor.

Mr. VONNEGUT. The enforcement of legislation prohibiting unlicensed seeding is a difficult problem. People who illegally seed either from the ground or from an airplane would be difficult to apprehend. A person dropping dry ice from an airplane is not easily detected nor is a person generating invisible silver iodide smoke perhaps in his furnace or fireplace. Furthermore, the equipment for either type of seeding is simple, cheap, and readily available. Instruments for detecting silver iodide smokes are being developed, and with their use it may be possible, to a limited extent, to detect and apprehend persons engaged in illegal seeding. Probably the most useful method to control illegal seeding is to make it clear to the public that operations of this sort are contrary to their own best interests and to the country as a whole.

Although there has been no question whatever concerning the validity of the initial laboratory work which led to the first cloud seeding experiments, there is still a considerable skepticism on the part of some scientific authorities concerning the economic value of cloud seeding. On the basis of my own experience, I feel with a certainty far greater than 99 out of 100 that cloud seeding can be of enormous value to our country. However, if I felt the chances were only 1 out of 100 that weather control was possible, I would still feel very strongly in view of its possible value to the Nation that no stone should be left unturned in pursuing its development. I believe that Federal legislation is vital to this end.

Senator ANDERSON. Do the members have questions to address generally now to Dr. Suits, Dr. Schaefer or Dr. Vonnegut?

Senator HUNT. Mr. Chairman, I would just like to reiterate here or reread, rather, one brief sentence which I am sure the press did not miss, but it is terrific:

> On the basis of my own experience, I feel with a certainty far greater than 99 out of 100 that cloud seeding can be of enormous value to our country.

Senator CORDON. Mr. Chairman, I have one question of Dr. Vonnegut.

When you interpolated with reference to instrumentation being developed for various purposes in measurement of these new values, I believe you said that one instrument that was being developed was for the purpose of measuring the nuclei present both for snow and rain.

Mr. VONNEGUT. For ice crystal formation, that is snow formation and water drop formation. By that I do not mean raindrops, I mean the very small drops less than a thousandth of an inch in diameter that form the clouds.

Senator CORDON. Do you have any hope of being able sometime to identify that nuclei?

Mr. SUITS. Yes.

Mr. VONNEGUT. Yes, to a certain extent. There are very sensitive physical and chemical procedures which can be used. The difficulty with these nuclei is that they are so very small. In other words, it takes about a hundred million million of them to weigh one gram, which is about a fifth of the weight of a nickel.

Senator ANDERSON. What was that, a hundred million million of them?

Mr. VONNEGUT. I am sorry, I made a mistake. A hundred hundred million million.

Senator SMATHERS. It sounds like a number in the budget.

Senator ANDERSON. A hundred hundred million million.

Mr. VONNEGUT. To weigh 1 gram it takes 1 followed by 16 zeros silver iodide particles.

Senator ANDERSON. You have to devise, then, a type of measuring device that gets down to dealing with particles that are relatively small.

Mr. VONNEGUT. We have such a device in Schaefer's cold box. We can take a sample of air which we want to examine and we put it in the cold box and blow in our breath. If we see a lot of ice crystals forming, we know that each one of those represents one of these particles.

Now for continued scientific work it is desirable to have a machine that operates automatically, one that you do not have to sit watching, and the development of this instrument is essential to the development of an automatic snowflake counter.

Senator ANDERSON. Are there other questions? If not, I will call Mr. Searles for a brief statement.

Senator CASE. I would like to ask one question. Admittedly the question of controls would be complicated by reason of the international aspect pointed out by Senator Smathers, but we have that problem in connection with broadcasting today.

Do you think that the problem of working out a system of licensing would be any more difficult or any more burdensome than the problem of licensing waves for radio when that was first considered?

Mr. VONNEGUT. There is a considerable analogy. I think that the big difference in the two types of legislation would be in detecting the seeding operation versus the detection of an illegal broadcasting system, I mean broadcasting station.

Finding an illegal broadcasting station is, as I understand it, a matter of triangulation and figuring out the general area to get it located, and you know that the radio waves go in straight lines, so to

speak, so that you can carry out a simple piece of geometry and get a pretty good idea where a transmitter is located.

However, with cloud seeding we do not know where our own silver iodide is going. That is one of our projects. That is one of the reasons we want these instruments, so if we detect silver iodide in larger quantities than we have used, we will know somebody else is putting it out. But so far as tracing this snake of smoke down, which maybe went up to altitude and then came down again, you have a much more complicated problem than with radio.

Senator CASE. Is that why you suggest that the use of dry ice lends itself more readily to licensing because you can take records of wind patterns or something of that sort to determine cloud drift?

Mr. VONNEGUT. I feel that people should be licensed to use that because I think that it is not a large-scale operation, and I do not think that you will complicate the analysis of all this work by these greatly extensive effects.

In other words, nobody is entitled to cause extensive meteorological effects covering large areas of the country just because he wants to get more precipitation for his farm or for his watershed.

Senator CASE. And also, in using dry ice which involves the use of an airplane, you could set limits to which the airplane might seed clouds by elevation or altitude?

Mr. VONNEGUT. I think probably it would not be necessary to attach such regulations at this stage of the game.

Senator CASE. Because in any event the result of using dry ice would be limited in its area?

Mr. VONNEGUT. Yes. When I say "limited in its area," I do not imply that you can have precision bombing or anything like that with your water. Dry ice seeding is a very extensive thing, and an affected area covering a thousand square miles would not be uncommon. However, you do not run the risk of having it extend for hundreds of thousands of square miles.

Senator CASE. A thousand square miles would mean an area maybe——

Mr. VONNEGUT. Thirty by thirty.

Senator ANDERSON. And that cannot damage the pattern of weather over the country, not greatly at least, but by steadily putting silver iodide into the atmosphere, you could make the weather, perhaps, or modify it thousands of miles away.

Mr. VONNEGUT. I feel that there is less danger with the dry ice seeding, although we cannot say this definitely; it seems quite reasonable if we have track of the people who are doing it and they give full report, it will be possible to evaluate that, and if it appears it does not have any effect, why continue it?

Senator CORDON. It does not take very much dry ice to cause some pretty sizable precipitation, does it?

Mr. VONNEGUT. Pounds, sir.

Senator SMATHERS. May I ask is it possible to color silver iodide? I do not know anything about it, but is there a practical way of giving it color so that you can observe where it would go?

Mr. VONNEGUT. I am afraid not. You can color silver iodide certainly and you could release dyes at the same time of your seeding.

However, the amount of silver iodide necessary to precipitate water is perhaps one part in a million million, and the amount of dye that

you have to see is maybe 1 part in 10,000,000, so that for every pound of silver iodide you would have to put out perhaps 100,000 pounds of dye which would be quite a problem, and I am sure the neighbors would not enjoy it, because they would get a high concentration.

In other words, it is just not feasible to use these amounts which would be required to tag. There are other methods for tagging smoke which I think can be developed.

Senator SMATHERS. Are there experiments now being conducted to find other chemicals which might be used besides silver iodide?

Mr. VONNEGUT. Yes, in our own laboratory there is work which at the present time is primarily concerned with improvement of silver iodide by modification.

Senator SMATHERS. You feel so confident that this will become a practical method of controlling water, we will say, and the elements that, in your opinion, it is necessary to have legislation now in order to provide for the very practical use of this program in the near future.

Mr. VONNEGUT. I think legislation is desirable and necessary to get the optimum development, because if people are releasing silver iodide all over the place, as Mr. Hall of the Weather Bureau pointed out, an analysis becomes impossible and postponing legislation to regulate the use of the seeding, I think, is to a large extent going to postpone understanding of what goes on.

Senator SMATHERS. In other words, what you said about legislation is designed for the development of, rather than control of, the program.

Mr. VONNEGUT. It is for both.

Senator CORDON. It would be better to say a controlled development.

Senator SMATHERS. Controlled development. In other words, you distinguish between legislation which is designed to see that no improper use is made of it, rather than legislation which is designed to bring about a development of it.

Mr. VONNEGUT. I think in my statement I cover several different aspects of it. I feel I have mentioned that I think legislation is necessary to regulate and legislation is necessary to provide funds and agencies to accomplish this.

Senator SMATHERS. That is all, Mr. Chairman.

Senator ANDERSON. Mr. Searles.

Mr. SEARLES. Mr. Chairman, with your permission I will read this.

Senator ANDERSON. Will you identify yourself even though you are a neighbor from Arizona.

STATEMENT OF RICHARD D. SEARLES, PRESIDENT, SALT RIVER VALLEY WATER USERS' ASSOCIATION, PHOENIX, ARIZ.

Mr. SEARLES. Yes, sir. I am R. D. Searles, president of the Water Users' Association just west of the New Mexico line, around Phoenix, Ariz.

Our association operates an irrigation project of 241,000 acres surrounding Phoenix, Ariz., and a hydroelectric system consisting of four major hydro dams on the Salt River and two major storage dams on the Verde River with a total storage capacity of approximately 2,000,000 acre-feet. Our watershed consists of 12,000 square

miles; approximately 60 miles wide and 200 miles long. I might comment we have 200,000 acre-feet stored today.

Senator ANDERSON. I am glad you made that comment. You are facing a gradual rising temperature and a decrease in moisture and a tremendous investment of the Government running into millions of dollars and still greater sums on the part of the people who own the land have already been invested in that area.

Now if it were possible to add to the supply of rainfall somewhat modestly that entire project would be greatly benefited and so would the Federal Government.

Mr. SEARLES. All projects would be greatly benefited, Senator.

Senator ANDERSON. It is a little bit off the beaten path, but would you comment as a practical farmer in that valley, which I know you are, whether or not the Government got its money back out of the Salt River project in income taxes alone.

Mr. SEARLES. Yes, sir.

Senator ANDERSON. Many times over?

Mr. SEARLES. And practically all of its money out of a $50,000,000 investment of which $20,000,000, I think, was Federal money, we now owe $5,000,000 on the latter. We have never missed a payment.

The total runoff from our watershed in the last 50 years has progressively decreased. In the first 10-year period from 1900 to 1910 our runoff was 18,000,000 acre-feet, or an average of 1,800,000 acre-feet annually; the next 10 years produced 15,500,000 acre-feet or an average of 1,500,000 acre-feet per year; the next 10 years from 1920 to 1930 produced 12,500,000 acre-feet, or an average of 1¼ million acre-feet a year; the runoff dropped in the next 10-year period to 10,800,000 acre-feet, an average of 1,080,000 annually, and in the last 10-year period from 1940 to 1950 it again dropped to 10,070,000 or an average of 1,070,000 acre-feet each year. Last year's runoff yielded only 411,000 acre-feet and this year we appear to be in one of the most severe droughts in the last 37 years. Apparently our runoff will not exceed 350,000 acre-feet unless we have exceptional storms on the watersheds in April.

Because of this continually diminishing runoff we looked with great interest on the first information regarding the rain-making experiments and discoveries that came from the General Electric laboratory and the work of Dr. Langmuir; Dr. Schaefer; and, later, Dr. Vonnegut. In the summer of 1948 we did considerable flying, using two different companies in an experimental work on rain making.

Inasmuch as it appeared impossible to judge any of the results against a normal or average year, we used the following basis in an endeavor to determine what increase in runoff we had obtained after a 6-week period in July and August in which we did extensive flying using both dry ice and silver iodide.

After measuring our resulting runoff, we went back through the records and looked for a year with cloud cover and weather conditions similar to the 6-week period in 1948. We then compared our 1948 runoff with the runoff of that year, which happened to be 1937, and with this comparison we determined that we had increased our runoff by 12,000 acre-feet during that period in 1948. The following winter we did extensive flying but did not begin our work until the middle of January, prior to which time we had had several large snowstorms, and, because of our inability to estimate the amount of precipitation on

the ground at the time we started flying, we were unable to definitely determine the amount of increased runoff due to our rain-making activities.

That particular spring we had a runoff of 1,330,000 acre-feet and did not do any additional work that summer. In the winter of 1949–50 we again used planes and ground generators. Last summer we again flew and used ground generators but did not do very much work because of the almost complete lack of cloud cover. I think those were the empties coming back from Mexico. We have been working this winter but have not been able to do very much flying because again we have not had any cloud cover.

In the course of this work we have spent approximately $120,000 over the 3-year period. We have experimented a great deal in the use of ground generators; our first one cost us approximately $2,000 and we have now built a more efficient and practical one for less than $100. We are deeply indebted to the gentlemen from General Electric for their cooperation and help, and the advances that we have made have been primarily due to their unselfish assistance.

I may be corrected, but the way they discovered the application of dry ice: They could not get the cold box cold enough one summer and were putting dry ice in to make it cold, and that is the way they discovered its use. Now they tell me they are using a cold spot.

During the time of our operations we have been visited by probably 20 different groups—from irrigation districts in the Southwest and Northwest; from agricultural communities in Mexico—and we have had correspondence with many foreign countries. Only recently we were visited by some officials from Chile who desired to study our records and discuss our operations.

To me the extensive research into the theory of artificial precipitation is an exploration that should be done on a broad basis for the good of the entire country, and it is my hope that Congress will see the possibilities that can be developed by the successful application of this theory of artificial precipitation toward the control of weather. With apologies, Senator Hunt, as Mark Twain's friend Charles Dudley Warner said, "Everyone talks about the weather, but no one does anything about it." Congress now has the opportunity to change that famous remark.

We have been quite fortunate in our rain making in that any increase in runoff that we got into the reservoirs behind our hydro dams was more than paid for by the additional power produced. Thus rain making is not only a boon to the farmers but to industry and all those that are dependent upon electric power for their operations. If we could increase precipitation by 10 or 20 percent on our watershed and the watershed of the Colorado River and of many New Mexico and California rivers, we would relieve many of our present problems, both as to power and water; and as our country grows and our population increases, we are going to have even more and greater need for both. The only answer that I know to this problem at the present time is to perfect the application of cloud seeding.

The $120,000 which we have spent on our work of artificial precipitation is a large sum of money for a project of our size, but it only emphasizes the desperate need that we have for more water, as do many other irrigation projects in the West. Also in many areas east of the Mississippi this technique could very well be applied in times of drought.

We would like to see two or three programs on artificial precipitation developed in different locations in the country for a period of 3 or 4 years. We are satisfied that the money we have spent and the work that we have done on rain making have been justified. However, successful commercial application of this scientific work is not going to be obtained unless the Government will finance it and handle its operation on a large scale in cooperation with local communities.

As a typical example, because I am familiar with the area, if the Government would set up an operation on watersheds such as ours, which is 12,000 square miles in area, there would be little difficulty as to damages and complaints from those living on it. In fact, the program probably would be welcomed by everyone on the watershed as they would benefit by any increased snow or rainfall produced. With such an extensive program all of us would learn during the 3 or 4 years better means of cloud seeding and have better ideas of the results and value that can be attributed to the work. It is very important that this work be handled by our Government because the cost of the actual evaluating of the work is greatly in excess of the cost of the application of cloud seeding. It is further vitally important that the Government do this work, probably in conjunction with the local government, in order to remove any element of promotion on the part of people who interest themselves in the work on a commercial basis.

The Government has at its command many sources of help and assistance which are invaluable to operations such as ours. For example, we would like to have the use of a T–33 jet trainer to fly at 35,000 feet altitude to observe the effects of our cloud seeding in the wintertime. Such observation would indirectly be of no cost to the Government as in our area the same jets are constantly in the air as the pilots are building up time and experience in flying them.

Another important reason that this work be handled by an agency of the Government is that it be familiar with the problem and interested in it. This work will never be successful unless it is handled by an agency that knows that the job has to be done and has to be successful. If we had not ourselves been in, and still are in, such a critical need for water, we, of course, would not have spent the money that we did on this work, and the fellow that has to have the water to live is surely going to be the one who succeeds in finding the means to obtain it.

We have found that the seeding in the summertime is of very little practical value to us unless we can create a violent or cyclonic type of storm. This is not because we are not successful in creating rain then, but that normally the runoff of the watershed is very much less in the summertime on to the reservoirs than in the winter with the same amount of precipitation. Most of the moisture goes into the soil up in the watershed. In the 8 months from October through May, records indicate that we obtain a runoff of 30 percent of the precipitation. In the summer months from June through September approximately 1 percent is obtained. The rain in the summertime, however, is invaluable to the cattlemen on the range.

In closing I would like to pay a tribute to Mr. Wilson, former president of the General Electric Co., because it was with his approval that this research has been carried on at great expense to his com-

pany. There is hardly any prospect of its profiting through this research. Any profit from it is going to be to the people of the country, and I know that is the attitude that General Electric has taken on this matter in having its laboratories doing this work.

I would like to summarize on this one point, Mr. Chairman. Your hearing here has brought out a very definite point, and that is that this cannot be at all successful if the people who handle it have a negative approach to it.

I think you may realize it or have noticed, without being critical, the only help that I had from the Weather Bureau was that every pamphlet they had which was critical of rain making got to every member of my board of directors. They saw to that.

Senator ANDERSON. Thank you very much, Mr. Searles.

Senator CASE. May I ask one question?

Senator ANDERSON. Yes, indeed.

Senator CASE. You spoke of the winter runoff or the winter operation being better for you. That is because you are thinking in terms of runoff because yours is an irrigation economy.

Mr. SEARLES. Yes, indeed.

Senator CASE. If you were thinking in terms of the Northern Great Plains, let us say, where you have a marginal situation with respect to rainfall and where the farms are not developed for irrigation, the work would be more beneficial during the growing season, would it not?

Mr. SEARLES. Definitely, yes; it would be very beneficial there.

Senator ANDERSON. May I ask you a question now? You say that your runoff this year is going to be very light and it looks like you may have less than 300,000 acre-feet. We have just been notified on our farm that we will not have irrigation water after June 1.

You understand what that means to a farmer who has permanent pasture and has invested a lot of money in it. That is gone. His alfalfa is gone and a great many other things.

Now do you think that your valley and the next valley to it and the valleys in Colorado might be better off if the Federal Government was either doing directly or contracting with somebody maybe to go far beyond the limits of your State or mine and try to build up cloud formations which you can tap?

Mr. SEARLES. It would be, Senator. Actually, probably with the exception of using dry ice in local areas, this work cannot be helpful to the country like it should be unless it is handled by one agency, because many ranchers, who can buy a generator now for $150 or $300 and think they can start it up and create a rain, do not know whether they are creating a rain or stopping a rain.

Senator ANDERSON. Explain that, because that is very important. I know what you mean, but these men may not.

Mr. SEARLES. Well, it is simply a question of overseeding and too much nuclei—too much silver iodide will stop the rain—and under certain conditions—you asked me a fine question with these gentlemen beside me, but there is a question that overseeding will stop a rain rather than start it.

Senator ANDERSON. I think it would be helpful if subsequently both of us asked Dr. Schaefer to comment on that a little bit.

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Mr. SEARLES. I think one example of it that I understand is that in Costa Rica they did extensive rain-making until they were forced to stop. In turn now they use it to stop thunderstorms or violent storms that knock the bananas off the trees, so they just reversed their application. It is very true that you are going to have to have Federal regulation of that.

In the first place it would take a long time to educate the average person as to how you have to apply a process. We have always retained scientists to supervise our programs. We would not attempt to try to do it ourselves.

Senator ANDERSON. I think that is the best part of your testimony and of your program, that you have retained the scientists, you have tried to do it in scientific fashion, and because you have done it that way you have not interfered with other people.

Thank you very much, Mr. Searles.

Tomorrow morning, then, we will have Secretary Chapman, Secretary Warren, Commissioner Straus, Mr. Bennett, and perhaps some other people who may be here.

(Whereupon at 12:50 p. m., an adjournment was taken until 10 a. m., Thursday, March 15, 1951.)

WEATHER CONTROL AND AUGMENTED POTABLE WATER SUPPLY

THURSDAY, MARCH 15, 1951

SUBCOMMITTEES OF THE COMMITTEES ON
INTERIOR AND INSULAR AFFAIRS,
INTERSTATE AND FOREIGN COMMERCE,
AGRICULTURE AND FORESTRY,
Washington, D. C.

The subcommittees met, pursuant to recess, at 10:10 a. m., in room 224, Senate Office Building, Senator Clinton P. Anderson, presiding.

Present: Senators Clinton P. Anderson, Herbert H. Lehman, George A. Smathers, Guy Cordon, and Francis Case.

Also present: Mills Astin, chief clerk to the Committee on Interior and Insular Affairs.

Senator ANDERSON. The hearing will come to order.

Mr. Secretary, I understand that you submitted a report on S. 5, which is the bill introduced by Senator O'Mahoney, and without objection that will be put in the record at this point.

(The report referred to is as follows:)

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

MY DEAR SENATOR O'MAHONEY: I am glad to comply with your request for an expression of the views of this Department on the bill (S. 5) to provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes.

This bill is based upon several previous bills and amendments thereto. These include S. 1300 and H. R. 3123, Eighty-first Congress, which you and Congressman McKinnon introduced, the amendments to S. 1300 proposed on January 5, 1950, by Senator Downey for himself and for you and Senator McFarland, and the amendments recommended by this Department in its reports of July 7, 1949, April 12, 1950, and June 23, 1950, to your committee (those reports appear in the appendix), and in its report of April 12, 1950, to the House Committee on Public Lands. Reference is invited to those reports for certain details not herein discussed.

Enactment of S. 5 would authorize this Department to engage in necessary research to develop economically feasible means of producing from saline waters, directly or from the atmosphere, water which is suitable for beneficial consumptive use.

Water shortages are acute throughout many areas of the West today, where many thousands of acres of irrigated land are being kept in production only through serious overpumping of the existing ground water. Pumping from ground water for irrigation in some of the most highly productive areas in California, Arizona, and New Mexico during the past few years has been at rates far exceeding the safe yields, as estimated by the United States Geological Survey.

Thousands of acres of fertile western soil await only irrigation water to be transformed into highly productive agricultural lands. With ample water for these

lands, opportunities would be presented for expansion of our traditional American farm-family way of life, and production of crops to feed and clothe our growing population would be greatly increased.

The fears of drought, with its devastation of farm capital and income and its repercussions in commerce and taxation, could be ameliorated and perhaps removed all over the United States with discovery of successful ways to obtain precipitation when and where it is needed.

Rapid increases in population in the Los Angeles, San Diego, and San Francisco-Oakland metropolitan areas of California during the 1940's and prospective increases there during the 1950's require an ever-continuing search for water. If the present emergency continues for long, the need for additional domestic and industrial water supplies in these and some of the other western cities may well become immediate and pressing.

Many eastern cities, including New York City, Norfolk, Baltimore, Philadelphia, St. Petersburg, Tampa, Mobile, and New Orleans, as well as midwestern and western cities, are vulnerable to drought; and sudden increase in the population or industry, such as that which would result from defense preparations or war, would cause serious water shortages in many areas.

Many areas throughout the Western States, because of soil characteristics, have water which is too salty, either originally or because of use and reuse, to be used for irrigation or for industrial and even domestic purposes. Such saltiness is minor compared with the concentrations of ocean water. Such problems can at times be corrected by dilution of the water, or by leaching of soils. But to do so requires an abundance of fresh water generally not available for such purposes.

Man's search for water is the history of the world. The Bible is full of the importance of water to the tribes of Israel. Egypt rose and fell on the flow of the Nile. The Great Plains area of the United States rose to a peak, then came to a disastrous slump from lack of water. Man has relied upon wells and the wells dried up; he has tried rivers, and the rivers dried up. Lakes and springs come and go with weather conditions. Few people realize the importance of water in their everyday lives. Water appears to be but an accomplished fact to the average person. But it becomes a fact only as the result of work, research, and vision.

The bill before you is a step forward in man's search. It is a visionary step.

The benefits to millions of our citizens that would follow successful development of economically feasible means of producing, from the oceans and other saline waters, water of quality suitable for beneficial consumptive use would be incalculable. The large-scale purification of the salt water of oceans either directly in conversion plants or by inducing precipitation of the moisture that nature herself has evaporated from the seas and transported inland is an opportunity that challenges not only the imagination, but the scientific resources of the Nation as well. Frontiers would be opened for development throughout the United States.

Converting salt water to fresh water is an everyday occurrence. Any school boy can do it with a teakettle. The problem is how to do it on a large scale at reasonable cost. Already we know that by compression-distillation methods fresh water can be and is being produced for a cost of nearly $180 per acre-foot. The limiting factor is energy cost. Perhaps use of solar energy is the answer. Numerous other methods have been and should be studied. Some already give promise of water at a reasonable price.

Evidence is also piling up that points to the conclusion that it is possible, under certain conditions not completely defined as yet, to cause some rainfall or snowfall artificially. However, the purpose of governmental research to date has been confined almost entirely to the study of cloud modification. Except for very meager studies by private firms, practical rain making to increase water supplies has not been an objective of research. I say this notwithstanding the fact that very large segments of our Western States are now undergoing commercial cloud-seeding operations based on very scanty knowledge of the consequences.

From present indications, it appears that the cost of producing rain or snow artificially may be remarkably low once the research and experimental work has been completed. It appears possible that the winter snow pack in certain mountainous areas might be increased in this way. Thus the total quantity of water available for irrigation, municipal water supply, and power production would also be increased. Much basic and applied research and field demonstration, however, will be needed before it can be said with complete certainty on what scale such operations are practicable and what the cost of the resulting product will be.

In addition to the direct benefits that might accrue from increasing the water supply available for beneficial consumptive use, the studies incident thereto may well lead to knowledge which will be useful in controlling or ameliorating air pollution—a serious problem is some areas. The increased run-off from the artificially produced rain or snow may, moreover, require changes in plans for future water-use projects and even in designs of dams and other works. If this additional water is to become available, its amount and location should be determined at the earliest possible date so as to avoid costly alterations of structures now being planned and designed by the Bureau of Reclamation and other Federal and private organizations. It is possible that some modification of existing structures may also be necessary.

The Weather Bureau of the Department of Commerce has for many years engaged in the measurement of atmospheric phenomena, the collection and analysis of precipitation records, and recently in the evaluation of techniques that have been suggested for producing precipitation artificially. The assistance of that agency and of all other organizations which have performed or are conducting research in this field will be sought.

I recommend the deletion of the word "transporting" in line 9, page 2, of the bill, and the word "transportation" in line 13, same page.

The committee may wish to consider adding to paragraph (g) of section 2 (p. 4, line 9) a proviso along the following lines:

"*Provided*, That prior to conducting any operations in the air the Civil Aeronautics Administration shall be consulted and no such operation which, in the judgment of the Administration, will constitute a hazard to the safety of air traffic within a described area and at a specified time if conducted at a proposed place and time shall be conducted at that place and time."

Your committee may also wish to add a new section between the present sections 2 and 3 reading as follows:

"The Secretary shall, with respect to the development of techniques for the production of water from the atmosphere, cooperate with the Secretary of Commerce to assure that the facilities and experience of the Department of Commerce are fully utilized. Research undertaken by the Secretary under the authority contained in this Act shall be coordinated or conducted jointly with the Department of Defense to the greatest practicable extent compatible with military and security limitations, to the end that research and developments under this Act which are primarily of a civil nature will contribute to the defense of the Nation and that research and developments in the same field which are primarily of a military nature and are conducted by the Department of Defense will be made available to advance the purposes of this Act and to strengthen the civil economy of the Nation."

We were advised by letter dated March 20, 1950, from the Acting Director of the Bureau of the Budget as follows:

"I am authorized to inform you that the President desires to have the Department of the Interior take the leadership in necessary research, experimentation, and demonstration designed to develop economic means of producing from sea water or other saline waters, water which is suitable for agricultural, industrial, municipal water supply, and other beneficial consumptive uses.

"The President agrees that statutory authority for the necessary work should be sought and requests you to take the lead on behalf of the Administration in recommending early enactment by the Congress of S. 1300 with certain amendments * * *."

All of the amendments thereafter suggested were recommended by us to your committee in connection with its consideration of S. 1300, Eight-first Congress, to which reference has already been made, and are incorporated in the text of S. 5.

I am advised by the Bureau of the Budget that there is no objection to transmission of this report to the Congress and that enactment of the proposed legislation would be in accord with the program of the President.

Sincerely yours,

OSCAR L. CHAPMAN,
Secretary of the Interior.

Senator ANDERSON. We are always glad to welcome the Secretary of the Interior to this committee and we will be glad to hear any statement that you may wish to make, Mr. Secretary.

STATEMENT OF HON. OSCAR L. CHAPMAN, SECRETARY OF THE INTERIOR

Secretary CHAPMAN. Thank you, Mr. Chairman. I have a statement that I would like to read into the record, in order to keep it carefully in continuity.

I want to say, following my own testimony, we have Secretary Warne with us, who will do more detailed explaining of these maps here before you, and particularly regarding the precipitation problem itself. I am confining most of my discussion principally to the distillation of salt water, but other witnesses will follow with the other phases. Mr. Straus is to testify and Mr. Bennett, who is the technical expert on these matters. He will explain these maps to you in detail and clarify them for you as he goes along in his testimony.

Senator ANDERSON. I think yesterday we were pretty largely devoting our time to rain making.

Secretary CHAPMAN. Yes.

Senator ANDERSON. But we do have before us, of course, this proposal of Senator O'Mahoney that deals principally with the question of the use of sea water for irrigation, salinity in streams. We are glad to have your testimony on that point.

Secretary CHAPMAN. I do not wish to leave the impression, because I have concentrated my discussion principally upon the distillation of sea water, that I am not just as interested in the possibilities of the induced precipitation and weather control.

I think there is a decided hope and possibility in the other, too, and I think it would be a serious mistake to get the impression that I am only interested in just one possibility because I happened to prepare my testimony on one phase. I wanted others, who have devoted more time to the subject than I have, to explain it.

Mr. Chairman, I am pleased to have this opportunity of presenting my views on S. 5, a bill to provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses.

In simple terms, S. 5 provides for research and demonstration on two fronts. The first relates to the conversion of saline waters to potable uses and the second to artificial precipitation.

I shall confine my discussion primarily to the importance and implications of the salt water-conversion features of the bill, which I have advocated for some years. The details of the artificial precipitation features will be discussed by other representatives of the Department of the Interior. My report as Secretary of the Interior on S. 5 has been cleared by the Director of the Bureau of the Budget and the report is submitted for the record.

The Department of the Interior has a major responsibility, on the part of the United States Government, for the development of the Nation's water supplies, their conservation and use. This responsibility is direct in the western area where the United States is the owner of vast areas of public land and has been exercised over the last half century through the reclamation program for irrigation, domestic and industrial water supplies, and hydroelectric power production. Recreation, wildlife preservation and related purposes are included in other programs.

Our concern, however, in all essential respects extends not only to all of continental United States but also to our Territories and insular areas. Global considerations have emphasized our responsibilities from the human standpoint, for after all is said and done all of our programs must be directed toward that greatest of all objectives—service to the people.

The world's population is increasing at the rate of 23½ million persons annually. In the United States the population gain is at a rate that will bring the Nation to a total of 175,000,000 persons by 1960. American cities, particularly those in the coastal areas, are expanding rapidly and in the West many present problems are directly related to that prime necessity of life—water for domestic, agricultural, and industrial purposes.

Acute water shortages in many areas throughout the world today heighten interest in the subject. These shortages are most severe, of course, in those countries where the greatest concentrations of the world's population are in extensive regions that are arid or semiarid, and require irrigation for production of agricultural crops.

In the United States, arid or semiarid lands, where the average rainfall is less than 20 inches annually and insufficient to support sustained agriculture, constitute more than one-third of the total area of the country. Out of this 700,000,000 or 750,000,000 acres, only a little more than 21,000,000 acres of land are now irrigated and hundreds of thousands of these acres are being kept in production only through serious overpumping of the existing ground water. Additional millions of acres of fertile soil are awaiting only irrigation water to be transformed into highly productive farms that will support greatly increased population in rural and urban areas. To meet rising population rates in this country, maintain good standards of living, and make up for the loss of good land from seepage of alkali, soil depletion and erosion, we must make more fertile acres productive through irrigation.

The expansion of irrigation in the West will increase the purchasing power and provide markets for manufactured and other products of other sections of the country. There is, therefore, an urgent national need for constructive action. With complete development of all known surface water resources, however, we can foresee little more than a doubling of the presently irrigated acreage in this country.

In this connection, pumping from ground water for irrigation in some of the most highly productive areas in Arizona, California, and New Mexico in recent years has been at rates more than double the safe yields as estimated by the Geological Survey. In many localities in those three States, the groundwater table has been receding from 2 to 12 feet per year because of overpumping. The same situation exists, although to a lesser degree, in other of the Western States.

Also, many areas throughout the Western States have water supplies which are too salty to serve such purposes as irrigation, industrial use, and domestic use. This salt may come from the soil, either naturally, or through irrigation use and reuse. Since the amount of salt in this water is usually much less than in ocean water, the problem can at times be corrected by dilution. But this requires an abundance of fresh water generally not available. Methods for removing or reducing the salt content to a tolerant degree would naturally follow through solution of the research problems proposed in the legislation you are now considering.

Municipal water shortages have also occurred, as, for example, during the drought of summer of 1949 in such widely separated communities as the metropolitan area of New York City, on the east coast, and at Santa Barbara, Calif., on the west coast. If the growth in population is a criterion, probably the most critical municipal water supply situations in the foreseeable future, however, will occur in the metropolitan areas of the Pacific coast.

Between 1940 and 1950 the Los Angeles, San Diego, and San Francisco-Oakland metropolitan areas of California increased in population from 4,590,000 to 7,090,000, a gain of more than 54 percent. Estimates forecast a 1975 population for the 3 areas of approximately 10,000,000, a further gain of 36 percent over the 1950 figures.

In the present national emergency, the need for additional domestic and industrial water supplies in these and other western cities may well become definite and pressing.

Members of the House of Representatives are fully cognizant of this most serious problem. Companion bills to S. 5 have been introduced in the House by Representative McKinnon, whose home is in San Diego, and by Representative John Phillips, whose home is in Riverside County, Calif.

Water shortages which already exist or are threatened in a large number of industrial and urban areas in the West will affect the health of millions of city dwellers, the safety of billions of dollars in property values, and the general welfare not only in the West but throughout the country. In many of these areas the existing urban and irrigated agricultural developments can be maintained over a period of years only if additional water supplies are secured. Similar conditions exist in the Virgin Islands and in other insular possessions of the United States.

Through the development of economical methods for wholesale purification of ocean waters, new frontiers would be opened for development not only in the western United States but throughout the world. The Department of the Interior is constantly alert to the necessity of exploring all water-resource potentials. We are not overlooking the possibility of obtaining this urgently needed water supply from other sources, such as through the distillation of sea water and through artificially induced precipitation.

Fortunately, we are not entirely destitute of water in any land area of the United States; we are not down to the "last water hole." But the problem has reached great proportions, and President Truman has recognized its seriousness. A year ago he requested me to take the lead in presenting this matter to the Congress with the view of securing legislation authorizing research and development for the conversion of sea water into supplies for agricultural, industrial, and other beneficial consumptive uses. The President also requested the cooperation of the Secretaries of State, of Defense, of Agriculture, and of Commerce, the General Services Administrator, the Chairman of the Federal Power Commission, and the Federal Security Administrator in this endeavor. I am happy to report generous cooperation from them and from others, including the Chairman of the Atomic Energy Commission and the National Security Resources Board, and the Association of Land Grant Colleges, particularly those located in the West.

One hundred and fifty years ago, Samuel Coleridge penned those famous words in the Rhyme of the Ancient Mariner: "Water, water, everywhere, nor any drop to drink." At that time and even now those words could be applied to all of the world's vast oceans, and, as well, to some of our large inland lakes, such as Great Salt Lake in Utah and Salton Sea in southern California.

Today, demonstrations have shown that it is possible to purify sea water by various methods. Nature's method of replenishing water supplies, of course, is by evaporating moisture from the ocean and precipitating it on the land. Man can imitate or supplement this natural process in several ways. He can increase precipitation from clouds by use of silver iodide, or ice pellets, or he can tap the ocean source directly, ridding sea water of unwanted salts by distillation by chemical and electrical processes, or by freezing out fresh ice crystals.

Where the necessity is sufficient, and when cost can be disregarded, the objective presents no problem. During World War II, vapor compression distillation equipment was provided to many units of the Army, the Navy, and the Marine Corps, when they were destined for basing on islands in the Pacific, certain of the islands in the West Indies, or in other arid locations throughout the world. Hundreds of thousands of United States troops were provided all or part of their fresh water supply through the operation of these distillation units. It is estimated by one manufacturer that by the war's end the Armed Forces had sufficient vapor compression distillation equipment in service to supply the daily needs of over a million men. Units of large size have also been found practical under other circumstances, notably those used for nitrate mines in Chile; at Curacao in the Dutch West Indies; and those recently installed for producing 720,000 gallons of fresh water per day along the Persian Gulf.

Distillation has been demonstrated to be feasible where cost is not a factor. But such locations are few, and only domestic water, even there, can be supplied. Industry and agriculture cannot be supplied with fresh water from the sea unless and until lower-cost methods can be found.

The problem in salt-water conversion, therefore, is largely one of reducing costs. It is estimated by the manufacturers that the largest vapor compression distillation units have been improved to such an extent that their water-to-fuel ratio is approximately 200 to 1, and that the cost of distilled water produced by them, including depreciation, fuel, cleaning, and all other operating costs might be as low as 55 cents to $1.50 per 1,000 gallons. This is equal to approximately $180 to $490 per acre-foot. Our objective is to develop, through extensive research and experimentation, means for producing fresh water in much greater quantities and at a fraction of those costs.

Water thus obtained could be made available for use in areas along the sea coasts, including cities, and in certain inland areas by exchanging it for other waters now being diverted to the coastal areas from interior streams. Thus fresh water now required for urban areas on the California coast might be made available for irrigation of additional fertile acres in the San Joaquin Valley and other areas of that productive State.

The consideration of long-range plans for the solution of our water problems, which we must face squarely, should not be confused today,

as some individuals and interests are inclined to do, with the short-range objectives of localities that are involved. To do so can only serve to lull the people into a false sense of security about water.

The short-range objectives, such as full use of the waters of the Colorado River and settlement of interstate controversies involving the stream, should be pursued diligently. But, in addition, we must be considering larger transbasin diversions, demonstration of the reclamation of sea water, and artificial precipitation of rainfall. One of the principal long-time advantages of sea-water distillation, of course, would be that of having an unlimited, inexhaustible source of water supply from the oceans that are still a major line of defense and would be a further basis of internal security.

I visualize this research as productive of far more than a little additional water for peacetime uses. One possible means of reducing the costs of sea-water purification would be to develop methods for extracting commercially valuable ingredients from the sea water as a byproduct of the process. Many of the elements and their derivatives present in sea water are now classed as strategic materials; chlorine, sulfur, magnesium, bromine, hydrochloric acid, hydrobromic acid, and sulfuric acid. The possible uses of seaweed should also be considered. Although the chemical industry has conducted such research in methods for extracting such materials from the oceans, the production of pure water has not been an objective. Advantage has not been taken of shared costs that would result from a dual-purpose process. Some manufacturers have, I am informed, developed high-temperature equipment which if developed to its ultimate usefulness might prove to be capable of separating certain products as one phase while producing fresh water as another.

Our friends in the Department of the Navy have shown that there is enough waste steam from existing plants in our large coastal cities that could be put to use to effect very appreciable reduction in the cost of distilling sea water—sufficient perhaps to provide an emergency supply for a large city like New York.

Closest interrelationship exists between the civil and the military uses of the results of this research, and I am happy to report that my associates in the Department of the Interior who have been surveying the field in preparation for any working program that the Congress may direct with respect to salt-water conversion have reported closest cooperation and assurance of future cooperative effort, from all branches of the Department of Defense and other agencies. Like many efforts today that serve both military and civil purposes, we must undertake in this effort a balanced program such as to maintain over a long period the basic civil productivity of our country upon which the sustained defense program that we now face must finally depend. To this end I urge the enactment of S. 5 with provisions for greatly accelerated programs of research and development.

The benefits to millions of persons that would follow successful development of economically feasible means of producing, from saline waters, water of quality suitable for beneficial consumptive use would be incalculable. The proposed large-scale distillation of salt water of our oceans is an opportunity that challenges not only the imagination, but the scientific resources of the Nation.

The Department of the Interior, under the authority proposed in S. 5, is prepared to coordinate the research activities of all Federal

agencies with respect to salt-water conversion. We will bring to bear on the problem of economic feasibility the full knowledge and skills of the scientists of the Federal Government and private industry. Our objectives will be to develop the best and most effective methods that can be used in a pilot plant to demonstrate the results that will speed the objective of this phase of the legislation. I might say that to use the term "a pilot plant" there is not quite correct, because as a matter of fact the Navy has passed the stage of a pilot plant on distillation. We are really talking about demonstration plants and the present need.

With respect to artificial precipitation, I favor such controls and regulations of artificial precipitation as the Congress may find necessary.

I urgently recommend the immediate enactment of S. 5.

Senator ANDERSON. Mr. Secretary, would you like to have Mr. Bennett follow you?

Secretary CHAPMAN. I think it would be preferable to have Mr. Warne. I would be glad to answer any questions you have to ask, but Mr. Warne I think, if he follows me, will go into the phase of the water-precipitation program.

Senator ANDERSON. All right, Mr. Warne, if you will, please.

STATEMENT OF WILLIAM E. WARNE, ASSISTANT SECRETARY OF THE INTERIOR

Mr. WARNE. Mr. Chairman, I shall not take long. I do not have a prepared statement, but I want to call your attention to a few items that bear on the artificial precipitation phases of S. 5.

The Secretary delivered to you this morning a report on S. 5, which indicates the nature of the history of the development of that particular bill. It was introduced in its original form last year by Senator O'Mahoney as a salt-water experimentation bill, and was modified by Senator O'Mahoney, and I think, then, Senator Downey and Senator McFarland, to include as well an authorization for experimentation in the artificial-precipitation field by the Department of the Interior.

The report on S. 5 contains two suggestions that the committee might wish to consider in addition to the language of the bill. One is that you might want to consider a proviso that the Civil Aeronautics Administration would be consulted before large-scale operations in vicinities that might interfere with the airlines. Another is that the Secretary would be requested to work in conjunction with the Secretary of Commerce and fully to use the facilities of that Department in the work of our Department, and likewise with the defense agencies.

The language for those two proposals is in the report. I would call your attention to section 5 of S. 5, which is a section that sets out the responsibility of the Federal Government in connection with the damages or claims that might result from experimentation. If you will recall the testimony yesterday, it was suggested that experimentation was being hampered, or rather responsible experimentation was being hampered, by the lack of a means of spreading the risk in this whole new field of endeavor.

This section was cleared by our Department and by the Bureau of the Budget, and I believe may offer a solution for that particular problem. Just a word about the importance of this whole field of experimentation in weather control or artificial precipitation.

Several years ago, I read an article by Dr. Findiesen. I think it was published in 1938. And Dr. Schaefer, who testified yesterday, called it again to my attention this morning. Let me read two sentences out of it. It said:

> The recognition of the fact that quite minute quantitative inappreciable elements are the actual cause setting into operation weather phenomena of the highest magnitude, gives the certainty that in time human science will be enabled to effect an artificial control of the course of meteorological phenomena.

And another:

> It can be boldly stated that by comparatively moderate expense it will be possible in time to bring about rain by scientific means to obviate the danger of icing and to prevent the formation of hailstorms. Through the energy transformations thus secured, various other phenomena, that is, temperature and wind, will be brought under a certain kind of control which perhaps never in a direct manner could to an appreciable extent be acted upon in the atmosphere. The colloidal meteorological investigations by themselves were the only assistance of research work on the means to get some control over the weather factors and have opened up a new field for their efforts. They obviously only can solve those various problems with the close assistance of aerology.

If it is true, Mr. Chairman, that there is a practicable means of controlling weather, of directing rainfall, there is nothing that could be more important to the people of our Western States, the people of the whole of the United States and, perhaps, to the people of the world. We, who have been working in this field of irrigation, know that 200,000,000 acres of irrigated land in the world today produces about a fourth of the food supply of the world. Where you can completely control the application of water in crop production, the production and its importance to the population is all out of proportion to agriculture otherwise.

If it should be possible to water the fields by artificial precipitation, or to increase the water supply in areas where irrigation is required, just to increase them, the benefits that would be offered to the peoples of the world would be on such a scale that it almost defies even imaginative appraisal today.

With the best of our scientists who have been working in the field saying repeatedly that it can be done, though they are not certain exactly how best it could be done, it seems it is time for the Government to take a real long look at the responsibilities it has in connection with such a promising venture.

Senator ANDERSON. You stressed something a little earlier that I thought might be helpful in understanding that this legislation is not just designed to serve a few dry spots in the West. You said it could be used to prevent hailstorms.

Mr. WARNE. That is right.

Senator ANDERSON. It might be used to prevent tornadoes and various other things, so that if it could be worked out to any appreciable degree, it would benefit all parts of the country, would it not, and not just the arid areas of the West?

Mr. WARNE. That is certainly true. We think of its value in connection with the places where the problems are dramatic; where we have arid lands, for example. If it is possible to augment the water supply of those lands, we see vast possibilities.

Where we have, as in Senator Case's region, tremendous hailstorms, we see the possibility of being able to prevent their formation. From my understanding of some of the experiments that have been con-

ducted, I think it is possible to prevent the formation of a hailstorm, turn it into a simple thunderstorm.

Tornadoes are simply much more violent storms of the same character as thunderstorms, and they might be controlled in this manner.

Senator Smathers yesterday talked about the possibility of doing something about hurricanes. We think of the application of the weather control in those highly dramatic situations, but if it is possible to control weather, the importance of it will be found in the universal application at some distant time of those controls. This would be out of all proportion in the benefits given to the applications that we can see today in these dramatic instances.

Let me call your attention to this map over here, Known Target Areas of Commercial Rain-Making Ventures. Note the location and the vast extent of the activities.

Several years ago, our Department began as close a tab as it could on activities that were going forward in this field. You will see that there is one experimental area in New York State. It is over the watershed of the New York City water supply, but otherwise the work has been largely confined to the arid regions of the West. You can see the problem areas in the West very clearly indicated by the fact that they are already the ones that are trying to operate in this field.

Now, you had explained to you yesterday, much better than I could, the potential problems that arise from indiscriminate seeding of the atmosphere with some of the nucleating agents such as silver iodide, and at the present time we are not familiar with the specific nucleating agency used by any of the people who have contracts like these [indicating] covering this map. There are hundreds of millions of acres covered by those experiments at the present time in California, Oregon, Washington, Montana, Wyoming, a vast area in Colorado, and virtually three-quarters of the State of New Mexico, and in Arizona.

Senator ANDERSON. I think it will be fair to color the rest of that map because the southwestern corner has now been filled with projects.

Mr. WARNE. Certainly, the need is felt by the people of those areas for attention to this problem. There are two dangers in the present situation. One is that a rather promising budding science may be brought into disrepute by failure of uncontrolled and inappropriate experimentation.

I can remember back to the time when rain making had a distinctly bad odor after Mr. Hatfield tried to break the drought in San Diego County in California in 1916.

Senator ANDERSON. He succeeded in breaking the dam, did he not?

Mr. WARNE. Rain succeeded in breaking the dam.

Senator ANDERSON. He was accused of it.

You do not have anything on your map up there that indicates there is any activity in the State of South Dakota, but Senator Case knows that a group of ranchers out there tried to do something about it and, they think, succeeded a little bit.

Senator CASE. There were several small experiments there last year, and right now Dr. Krick's organization has been holding a series of meetings with farmers through the Plankinton-Kimball area, with which Senator Anderson is familiar.

Mr. WARNE. We would not say for a moment that that map indicates all of the areas in which the work is being or has been done. It does not show 1951 contracts, for example.

Senator CASE. I think the point should be merely though that the interest is certainly on the increase. The papers are reporting meetings night after night in various areas where from 30 to 100 farmers are meeting with representatives of these commercial organizations that are now seeking to get contracts, and they are putting these contracts even on a contingent basis, a small down payment, and the balance of the payment contingent upon them increasing the average precipitation over the area served.

Senator ANDERSON. That is going to bring up a nice question, because the farmers in southwestern New Mexico signed up one day, and long before a plane could get there natural forces deposited about a third of an inch of rain across the area, so the contractor got what might be called a windfall.

Mr. WARNE. I would like to point out—you remember some of the testimony yesterday—Dr. Vonnegut, I think, particularly said that the use of silver iodide might have an effective period longer in time than ice crystals, dry ice, and, perhaps, extremely wide effects. Now, just imagine the potential that is being established here as in all of these various target areas where nucleating agents are being released.

Senator LEHMAN. What do you mean by a target area?

Mr. WARNE. Those are the areas in which attempts are being made to increase the precipitation.

Senator LEHMAN. You have almost all of New Mexico shown as the target area. Are experiments going on all over New Mexico or only in one or two spots?

Mr. WARNE. These are not really experiments, Senator Lehman. Most of this work is work that is being done under contract by someone who says that he will do certain things and attempt to make rainfall. They are operations. Sometimes they seed fairly wide areas and sometimes they seed small areas. The point that ought to be kept in mind is this:

You had testimony here yesterday that silver iodide introduced as an invisible spray into the atmosphere, might have effect over long periods and vast areas far removed from the place of release, so while these are the target areas the effect conceivably could be felt anywhere.

Senator ANDERSON. I just want to point out there that a Denver newspaper in commenting on this activity of this one organization which has moved its headquarters to Denver says:

> Latest reports show that Irving P. Krick and his water resources firm have signed or are negotiating contracts for rain increase attempts next summer in parts of all these States: Texas, New Mexico, Arizona, Utah, Colorado, Wyoming, Nebraska, Kansas, Oklahoma, and Montana.

Senator CASE. Mr. Chairman, you should add to that South Dakota, because Dr. Krick's organization has a representative by the name of Reetz who has been meeting these farmers in South Dakota, and the accounts are being largely reported in a daily newspaper of which you were once the managing editor, the daily newspaper at Mitchell, S. Dak.

Senator ANDERSON. May I just point out that if ranchers and farmers generally are finding it necessary to go out and make contracts of this nature, does it not indicate that the Government might be justified in taking some slight interest in what is going on?

Mr. WARNE. Oh, I think the Government would be remiss in its obligation to the people as a whole if it did not take an interest in this thing in the very near future.

Senator ANDERSON. This article in the Denver Post says:

> Silver iodide will be scattered in all likely looking clouds next summer over some 200,000,000 acres.

Now, if you covered 200,000,000 acres and put silver iodide into all the likely looking clouds, the testimony yesterday would indicate it could have some pretty strong implications for all parts of the United States.

Mr. WARNE. The direction of the winds from those areas of seeding would determine where other areas might be affected. This is a matter, it seems to me, that we ought to be much more interested in than we have been. It seems to me that the operation has developed rapidly, the growth has been quick. The need for rain is there, the people are anxious to do something, anything that promises relief, and we have a situation that may get out of hand.

Senator LEHMAN. I was not here at the hearing yesterday, but I understand that it is proposed or stated that the use of silver iodide should be controlled by some governmental agency, but that there was no need of controlling the use of dry ice.

Mr. WARNE. Dr. Vonnegut of General Electric, as I understood his testimony, said that the Government should control the use of silver iodide because of the possibility of its having effect at great distances and at later times, but that he thought the effect of the use of dry ice was so local in character that the only control needed with regard to it would be a simple license from the Government. Again, I believe that is a type of control—a license.

Senator LEHMAN. May I ask you this: In New York, of course, they undertook this work for the purpose of relieving a drought or a probable drought. Did they use silver iodide or dry ice there; do you know?

Senator ANDERSON. Dr. Howell is going to testify directly.

Mr. WARNE. I cannot answer that for certain, Senator. I think they used both, but I would not be certain of that.

Senator CASE. Mr. Chairman, this point that has just arisen relates itself to a legislative problem that the Congress will have, and that is the definition of what agency should have the general control if we accept the thesis that the silver iodide presents a different problem than the dry ice.

Then we are also going to have the legislative problem of fixing the responsibility for those two areas, and I wondered, since Mr. Warne is representing the Department of the Interior as Assistant Secretary, if he would care to comment—and you may want to bring this later into the discussion—as to what phase of the problem would be particularly suitable for administration by the Department of the Interior and what phase of it might be suitable for control or operation by some other agency of the Government.

Mr. WARNE. S. 5, one of the bills before you, and the one that we reported on here, would extend the authority of the Department of the Interior in the field of experimentation. It does not set up licensing provisions. We do have agencies in our Department which have had experience with licensing on similar scales.

We suggest that our Department be authorized to conduct the experimental work with the artificial precipitation, with all methods, and the bill would set up the Department to do that work.

Senator CASE. Mr. Chairman, I would like to say at this point it seems evident that, in the absence of any barrier set up by the Government, this thing is going to go on, the Weather Bureau to the contrary notwithstanding; that is the evidence that you read there and the fact that ranchers individually are buying generators to use the silver iodide, and that others are employing planes to distribute dry ice. The thing is going ahead unless the Government sets up a barrier and says, "You shall not."

Now, then, you have these two areas that are being suggested by the comment of Dr. Vonnegut yesterday that two different problems are presented. We also have a problem in agencies, as is evidenced by the fact that the Bureau of Reclamation or the Department of the Interior, as Mr. Chapman's statement said, has a major responsibility in the development of auxiliary water supplies.

At the same time, the Department of the Interior and the Bureau of Reclamation have not had a complete coverage of the agricultural area in a grass-roots sense such as the Soil Conservation Service has presented in the Department of Agriculture, and I am just raising a point here because I think it is a thing we have to feel our way on and do some thinking about, whether or not these two divisions between the silver-iodide area and the dry-ice area suggest a logical division between the respective fields in which the Department of the Interior might operate and that in which the Department of Agriculture might operate through the Soil Conservation Service.

That is, if the scientists say that the dry ice is a local proposition, it might lend itself to supervision by and cooperation of the Soil Conservation Service, whereas the over-all or the larger field of silver iodide might lend itself more perfectly to the Department of the Interior. I just suggest that for thinking. I do not know what the answer is.

Senator ANDERSON. I think the committee, when we get farther along, is going to have a hard problem with that one matter because, as we saw by the testimony yesterday, the Weather Bureau is anxious to administer whatever program is undertaken.

There are the Taylor grazing areas, where the Department of the Interior has specific responsibility. There are also the forest areas, where the Department of Agriculture has responsibility; and then the Soil Conservation Service, which is generally in the Department of Agriculture again, has a great deal of land in this country organized into soil-conservation districts.

However, the real problem is that the Army and the Navy and the Air Force, cooperating with General Electric, have probably done more work in this field than the Weather Bureau or the Department of Agriculture or the Department of the Interior, and what I am hopeful of is that we will not come out with a solution that will interfere with the experimental work now being done by the Army, Navy, and Air Force, nor by those private individuals who could do a whole lot more if given a chance.

I think, for example, that we would have a pretty good answer on some of these problems if long ago we had had permission for experi-

mental work to be done without the possibility of the accumulation of damage suits against a large corporation.

In other words, when Dr. Schaefer did his first ride above that hurricane he could have followed it with additional rides and additional attempts to see if he could control the hurricane, and it might have been very helpful; but he had to recognize the possibility that General Electric would face several hundred million dollars' worth of suits if he happened to turn the hurricane in the wrong direction.

I think that we ought to realize that the provision of the bill which makes it possible for the Government to undertake that character of work or subcontract it to a group and require damaged individuals to sue the Government instead of an individual corporation would make it possible for great strides in this business.

As I contemplate it, as I see it, it is not going to be very essential to regulate the individual user of dry ice. He is operating from an airplane. His activities might be observed, maybe not as carefully as we would like, but they have a possibility of observation.

He has to take off from some sort of field and land again. He operates in a very narrow field, and I am not greatly worried whether he is licensed as long as he would perhaps just report what he does. If we got simple reports, I think that would be useful.

The great danger, as I see it, is that silver iodide being sprayed in every one of these States that are mentioned here, and perhaps every person in those States deciding to do a little generating, might result in such a disturbance of ordinary cloud patterns that we could have drought all over half the country and floods all over the rest of it, and put our defense mechanism out of kilter far more effectively than five atomic bombs could ever do.

Senator CASE. There was an article by Paul Friggins in the Country Gentleman the other day of a man who tossed a handful of silver iodide in the sawdust burner of a sawmill to see what would happen.

Senator ANDERSON. Any person who can take a small part of it and heat it can put it in his own fireplace and out of his chimney may go something that may neutralize the scientific work being done by somebody else just down the road, because actually unless you have a controlled experiment you have no way of finding out what is going on.

Mr. WARNE. The position of our Department before the committee is that we believe we ought to be authorized and directed to undertake the experimental work in this field.

The bill that is before you here by Senator O'Mahoney sets up appropriate provisions for that endeavor, including the provision that we could operate through and with agencies such as General Electric, the State College of New Mexico, and others who have been doing important work in this field, and we could run out controlled experiments within reasonable limits on various methods and devices. It would not prevent other departments, such as the Department of Defense or the Weather Bureau, from carrying on work that they are already doing.

Senator CORDON. There is no need of two people doing the same thing and spending the taxpayers' money, however.

Mr. WARNE. We would hope that in this way we could get a coordinated program.

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Senator ANDERSON. In any event, you know that you ought to be in on the group somewhere; do you not?

Mr. WARNE. We feel very strongly, as that map up there will show, the interests of the people in the irrigation areas is such that our Department ought to be doing something about it.

Senator CASE. There is one other interest of the Department of the Interior that ought to be mentioned, and that is the possible fire control in national-park areas, because, of course, if a national park like Yellowstone is ever visited by a major fire, it helps to destroy what makes the park.

Mr. WARNE. Each one of our bureaus—Indians, Parks, Land Office, Geological Survey—has an interest in it, but when you come right down to it, every living soul on the planet has an interest in this problem.

Senator LEHMAN. I do not make this as a suggestion because I certainly have not thought it through. It is a matter that the committee will have to consider at great length; but, unless you have some single agency to control this, are you not going to be confronted with differences of interests in various departments?

For instance, the Department of the Interior has an interest of a certain kind. The Department of Agriculture, of course, has a specific interest with regard to the raising of foodstuffs, and what might affect the raising of foodstuffs in certain parts might seriously affect the interests of the Park Service. Unless you have some single coordinated agency, are you not going to have those differences of interest result in conflict very frequently?

Mr. WARNE. We certainly believe that leadership in the Government's experimentation ought to be fixed by the Congress. I do not think that means necessarily, Senator Lehman, that a specific line of research, of interest to, let us say, the Department of Defense should not be carried out and conducted by them, or a specific line of research of interest to another Department, Agriculture, let us say, if Interior should be the leader, should not be conducted by Agriculture. I quite agree with you there ought to be a coordinated program here.

Senator ANDERSON. Secretary Warne, one question that occurs to me is this: Your map stops with the State of Washington in the Northwest. From the standpoint of weather, perhaps Alaska is more important than Washington; is it not?

Mr. WARNE. The Gulf of Alaska is the great storm generator that affects our continent.

Senator ANDERSON. And, if you are to affect the weather of all the United States by experimentation in a single spot, it might be in the Gulf of Alaska; might it not?

Mr. WARNE. It is in the Gulf of Alaska that the three air systems, the polar system, the moist warmer oceanic system and the cold dryer Asiatic system from the Gobi Desert come together and generate the storms that come in various tracks across the continent. Certainly most of our weather is made right up there; generated there anyway.

Senator ANDERSON. You think, because of the responsibility for the Department of the Interior for working in Alaska, it would certainly indicate the desirability when we get into the writing of final legislation of realizing the importance of the Department of the Interior.

In my own bill, S. 222, I set up the Secretary of Commerce as a member of the committee because of the activities of the Weather Bureau, and provided for several people from private life on the theory that, as they did with the Atomic Energy Commission, they might have to go back and have that committee work with the Army and that committee work with the Navy and that committee work with the various agencies just as the Atomic Energy Committee has had to work with the various agencies of the Federal Government.

You have a very good case as to why Interior can be in it, but we are going to have Dr. Barnes on tomorrow, from the Agriculture Research Administration, and he has a very good case as to why Agriculture should run this. You heard the case the Weather Bureau made yesterday. I did not think it was too good, but they made it.

Mr. WARNE. Mr. Chairman, we have a distinct interest in it. We have a great Department that is organized in such a way as to be useful in a situation of this sort. Now, I am a pretty good bureaucrat, but I am not a good enough one to say that no one else in the Government could do a satisfactory job here. That is up to you people.

We do believe that our interests are immediate; that the areas that we serve and the programs that we serve are more immediately concerned. We are ready to undertake the job of working out the program.

Senator ANDERSON. Let me ask you one other question here. I suppose Commissioner Straus would deal with this; but, generally speaking, you have reclamation projects all through that area where this experimentation is going on?

Mr. WARNE. That is right.

Senator ANDERSON. If by any chance experimentation should result in overdoing the job and there should be overseeding, you would find some of your reclamation reservoirs dry; would you not?

Mr. STRAUS. Or flooded.

Senator ANDERSON. Or flooded. You have both possibilities, and what I am trying to get at is: You do have an interest in the ultimate outcome. Either it does produce more rain or it does not, and you certainly have a very definite interest because of your interest in reclamation.

Mr. WARNE. The point that the map makes clear is that the work that is being done presently is concentrated largely in the areas where we are working on other programs to solve a similar problem of providing water in dry areas, the Missouri River Basin, the whole of the Western States, and it is there that attention needs to be given now.

Senator CASE. Mr. Chairman, I certainly feel that the Department of the Interior has a major responsibility in this field, but I think we ought to keep in mind, particularly in the Great Plains area, that you have a larger part of the acreage in land that is not susceptible to irrigation; and I do not believe Mr. Warne would suggest that in the Great Plains area, where the irrigated acreage is a small proportion of the total, you now have an organization set up for dealing with the range lands and the bench lands and the rough lands which are in a large part now organized in soil-conservation districts.

Mr. WARNE. We certainly do not have organized districts such as the soil-conservation districts in States like North Dakota and South Dakota, except in smaller areas, irrigation districts and that kind of thing. That is true.

Senator ANDERSON. I do believe it would be helpful, Secretary Warne, if you would submit to the committee later a brief statement as to why a good deal of this work possibly should center in the Department of the Interior, bearing in mind the point that Senator Case makes which I think is a very valid point, that there are many States where the Department of the Interior is not actively working. Even though Kansas, which is a State that had no reclamation, is now coming in and doing some reclamation work, generally speaking there is very little of it in States like Indiana, Illinois, Ohio, and so forth.

Mr. WARNE. That is true, but I would point out, Senator—and I will be glad to provide you with a statement on it—that rain making, if it becomes practical, either is of interest because it solves water problems or because it creates water problems, and the water agencies of the Government are pretty well concentrated in the Interior Department.

(Secretary Warne subsequently supplied the statement requested as follows:)

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., March 19, 1951.

Hon. CLINTON P. ANDERSON,
United States Senate, Washington, D. C.

MY DEAR SENATOR ANDERSON: During the hearings before the Senate joint subcommittee to consider S. 5, S. 222, and S. 798, you asked me to submit a statement on the reasons why research into artificial inducement of rain should be conducted by the Department of the Interior. The Interior Department is the single governmental agency most concerned with the long-time development and conservation of the Nation's resources. Weather modification offers possibilities for multiplying these resources, and it is logical to me that governmental research on the subject should be concentrated in an agency which focuses its attention on the solution of problems of resource development and conservation.

The Hoover Commission on Organization of the Executive Branch of the Government concluded that maximum benefits were to be obtained by harmonizing within one Department insofar as possible all governmental functions pertaining to natural resource development and conservation. Important scientific and technical research which would broaden these uses is already being carried on in the Bureau of Mines and the Geological Survey. Their endeavors received high praise in the Hoover Commission Task Force Report on Natural Resources, and I have every reason to believe that research work into artificial precipitation could be carried out with the same degree of excellence.

The Interior Department is an existing agency with well developed administrative facilities and procedures that are available for use with little expansion in assuming new assignments. There are many reasons that argue for use of an existing agency rather than the creation of a new agency when a new assignment is being given. They have been given often and I will not repeat them here. To me they seem conclusive.

It is fully intended that the facilities and talents of all existing governmental and private organizations will be completely utilized and S. 5 so provides. Private organizations and individuals have stressed the need for protection from damage suits in the conduct of further experiments in the air. Section 5 of S. 5 affords this protection. It provides that the United States shall assume responsibility for damages caused by any person or persons performing rain-making operations under contract with the United States.

S. 5 does not provide for licensing and control of weather modification experiments and operations by private organizations. If it is the Congress' wish to regulate these activities, the Department does not oppose establishing the regulatory function in another existing departmental agency.

Sincerely yours,

WILLIAM E. WARNE,
Assistant Secretary.

Senator LEHMAN. May I ask one question. Of course, research and experimentation is the first and probably the most important phase of this entire operation.

Mr. WARNE. That is right.

Senator LEHMAN. But if the use of silver iodide and possibly other materials is as promising as has been described here at these hearings, then we are going to come into the phase of operation and administration. I am just exploring this thing.

Unless you have a central agency that can say to this area, "You may or you may not carry on operations with silver iodide," or whatever the operations may be, I cannot get away from the fact that you are going to have great conflict.

If New York carries on an operation with silver iodide, it might very greatly affect the interests of Pennsylvania, Ohio, or even farther west.

Mr. WARNE. Or east.

Senator LEHMAN. And certainly the interests of rain making for water supply, rain making for irrigation of arid lands, or rain making for the Park Service, those interests are pretty divergent and I am wondering whether you will not have to set up a central agency for this.

Mr. WARNE. Senator Lehman, the Department of the Interior is the home agency of the Government. The fact that it is doing the reclamation work in the West does not make it a regional agency. It has a regional program there. That is all.

Another department could be set up, of course, but it would have identical jurisdiction with Interior so far as area is concerned. The jurisdiction of the Department of the Interior is not limited to any area or region. It is simply that some of its programs are directed at particular regions. Just as the Department of Agriculture has jurisdiction throughout the whole of the United States, some of its programs are localized, too.

The Interior Department is a logical department for operations of this kind, new operations that affect the physical and economic life of the country.

Senator ANDERSON. I think that we had better argue that in committee. We have a lot of witnesses here.

Did you have a statement, Commissioner Straus?

STATEMENT OF MICHAEL W. STRAUS, COMMISSIONER OF RECLAMATION, DEPARTMENT OF THE INTERIOR

Mr. STRAUS. Yes; I would like to make a statement.

I am Michael W. Straus, United States Commissioner of Reclamation, and am testifying as such.

The United States Government has made an investment of approximately $2 billion in the development of water and power in this country through the United States Bureau of Reclamation, which has thus become the Nation's principal water conservator and handler. Others have spent larger sums. All reclamation basically starts with finding sweet water somewhere, conserving it, getting kilowatts from it, transporting it, and delivering it to where it is needed. Therefore Reclamation has a vital interest in these bills concerning artificial

precipitation, salt-water conversion, and the development and control now before you. Reclamation looks to the Congress for guidance in welding these arts into an established responsibility.

Naturally I appear before you with a view to the interests of the water and power users of the West. They and we are confronted with an actual and real and daily problem in matters of conversion, precipitation, and their control. That problem can only be solved by the Congress and Reclamation commends this legislation to you for action and recommends such action.

We did not go and ferret out this problem and submit it to you. Progress and development created the problem and we have been confronted with it. In fact, we laid it before the Eighty-first Congress and now request the Eighty-second Congress to chart out the ground rules and national policy by which we may proceed in the public interest to bring these new developments to the full service of the country.

As the world's greatest accumulator and distributor of water and generator and transmitter of kilowatts wrested from that water, as well as builder and custodian of the Nation's reclamation investment, Reclamation has, naturally, been alert to and kept a close watch on artificial rainfall developments as they progressed for a number of years. This was made possible by the courtesy and cooperation of the Army-Navy-General Electric groups engaged in Project Cirrus, and the cooperation of the United States Weather Bureau, plus several universities and private concerns. Reclamation considers that artificial precipitation represents a tremendous scientific development to be recognized by any agency devoted to water conservation and use. We view conversion of sea water as a very possible source of additional sweet water. We recognize new potential national assets and we are perhaps more cognizant than those not experienced or responsible for handling great water supplies with the inherent conflicts and dangers in entering such fields in the absence of establishment by Congress of national policy for those fields by such measures as are before you.

The new and as yet not fully developed arts of precipitation and conversion must be, Reclamation believes, encouraged, appraised, assisted, and controlled to serve our citizens. That you will do as a result of your considerations. Water in rivers, as well as salt water in the ocean and moisture in the clouds, is a notorious insurrecto. It disregards completely local boundaries, district, county or State lines. Water willfully runs downhill or falls where it pleases. In clouds, it frequently rises instead of falling. I know no other organization than the Federal Government that is capable of tackling a problem of the breadth and scope that is now before you. The full resources of that Government are required to encourage and develop these arts, keep the books on the variety of practices now going on so that some firm economics may be established in appraising them, fashion some needed measuring rods, and then provide the ground rules of control.

So that the committee may have some information as to the current extent of the practices concerning which you are considering legislation, Reclamation wants to submit here a summary survey of efforts now going forward. We can identify by name 100 counties which are targets for commercial rainmaking. Replies of surveys disclose

a variety of schemes for rainmaking, embraced a number of methods for payment, and existence of an assortment of sponsoring associations, groups, and interests. Many are irrigation districts with which Reclamation works. Charges for rain-making surveys range from 1½ to 12 cents per acre, when an acreage basis of charge is employed, while other contracts are on a flat rate. Great metropolises, cities, towns, irrigation districts, associations of farmers, and all manner of organizations are dabbling in the business. One commercial firm alone is reported to have rain-making contracts with a target of 100 million acres. Other operations probably double or treble this acreage.

This survey is definitely incomplete. I am convinced it is an understatement of existing practices. I do not know that there exists anywhere a competent and complete statistical inventory of current rain-making operations. That is one most valuable byproduct legislation would yield. Nevertheless, the summary inventory Reclamation has made in its own studies of this problem is informative and positively indicative of vast and growing scope. Therefore, with your permission and for your convenience, I offer separately here the replies on the rain-making practices received to date in response to our inquiry. These are telegrams received in the last few days.

(The telegrams referred to are as follows:)

BOISE, IDAHO, *March 12, 1951.*

COMMISSIONER.
Subject: Artificial precipitation.

Warm Springs and Vale, Oreg., irrigation districts jointly attempting artificial precipitation on about 120,000 acres. Malheur River water used in Malheur and Harney Counties, Oreg. The districts have contracted with the Farmer's Air Service, Hermiston, Oreg., on a stand-by basis for $750 per month plus actual flying time at $50 per hour to seed dry ice by plane. Total estimated expense December through February $4,000.

The districts have also purchased two small silver iodide generators to experiment on ground level this spring. We know of no other water users' organizations trying rain-making in region 1.

TULLER.
Operation and Maintenance Supervisor.

BOULDER CITY, NEV., *March 13, 1951.*

BUREAU OF RECLAMATION.
Subject: Artificial precipitation.

Following is best information available short notice:

(1) Water and power agencies engaging in artificial precipitation are Salt River, City of San Diego, and California Electric Power Co. at Riverside, Calif.

(2) Salt River employs the Precipitation Control Co., 2431 East Buchanan Street, Phoenix, San Diego employs North American Weather Consultants, Pasadena; California Electric Power Co. uses own forces.

(3) Salt River target area 8,250,000 acres; San Diego 1,100 square miles; California Electric, 60 square miles.

(4) Salt River target area encompasses Yavapai, Coconino, Navajo, Apache, Gila, and Maricopa Counties, all in Arizona. San Diego watershed area covers only San Diego County. California Electric, Inyo County.

(5) Salt River contract price $100 per hour for actual time in air from Phoenix Airport, including all materials. January and February 1951, flying time was 58 hours and 35 minutes. Association also operates several silver iodide ground generators with own forces.

San Diego Contract price, including all materials and risk, approximately $10,000 for activity in months January to April, with option of extending through April for additional $2,500. North American uses ground generators only, using plane for scouting clouds. California Electric spends about $10,000 annually.

MORITZ.

SALT LAKE CITY, UTAH, *March 12, 1951.*

BUREAU OF RECLAMATION.
Subject: Artificial precipitation.

Newspaper accounts indicate that an organization composed of farmers and ranchers in Montezuma, Dolores, San Miguel, and La Plata Counties, Colo.; San Juan County, Utah; and San Juan County, N. Mex., have contracted with Water Resources Development Corp. of Denver, Colo., and Pasadena, Calif., headed by Dr. Irving Krick, for artificial rain-making experiments this summer. No information available as to contract price or other particulars.

Time does not permit contacting field and operating offices, but have not heard of other definite rain-making activities in region 4.

LARSON.

AMARILLO, TEX., *February 12, 1951.*

COMMISSIONER.
Subject: Artificial precipitation.

No irrigation district has contracted with rain-making firms. Organization and individuals within districts have contracted with Water Resources Development Corp., headed by Dr. Irving P. Krick, meteorologist. New Mexico and Southern Colorado covered by contracts. New Mexico total estimated at $105,000. Target area for the Rio Grande project mountain ranges in Rio Arriba and Sandoval Counties, N. Mex. Other contracts principally for rain making directly on owners' land. Details in photostats of press releases transmitted February 21, 1951.

THOMPSON, *Acting.*

BILLINGS, *March 13, 1951.*

COMMISSIONER.
Subject: Artificial precipitation.

Reurt above subject dated March 9, 1951, following information furnished for this region.

Local contracting unit and rain-making firm:

1. Tri-County Rain Improvement Association, Olson & Taylor Corp., Shelby, Mont.
2. Northeast Montana Rain Increase Association, Olson & Taylor Corp., Shelby, Mont.
3. Three River Weather Research Corp., Water Resources Development Corp., (I. P. Krick), Pasadena, Calif.
4. Unknown, Water Resources Development Corp. (I. P. Krick), Pasadena, Calif.

Acres in target area and location:

1. 850,000 plus, Hill, Liberty, Toole, and Choteau Counties, Mont.
2. 6,400,000, Daniels, Sheridan, and Roosevelt Counties, Mont.
3. 1,500,000, Jefferson, Madison, Gallatin, and Broadwater Counties, Mont.
4. 6,700,000, Powder County, Mont.; Sheridan, Johnson, Converse, Niobrara, Natrona, Weston, Crook, and Campbell Counties, Wyo.

Unit price	Maximum price	Status of contract
1. 10 cents per acre	$85,000	Signed to start May 1.
2. 11 cents per acre cropland; 5 cents per acre grassland	None given	Being negotiated.
3. 12 cents per acre cropland; 6 cents per acre grassland	None given	Do.
4. 1½ cents per acre	100,000	To be signed Mar. 7.

All of above contracts propose use of silver iodide crystals with ground generators.

VERNON.

DENVER, COLO., *March 12, 1951.*

Bureau of Reclamation
Subject: Artificial precipitation.

All contracts for artificial precipitation have been with Water Resources Development Corp., Pasadena, Calif., Krick and Associates. Names of water users' associations not generally available. Local contracting groups have been

loose associations of local interests, with funds raised by contribution, and not identified with water user associations for irrigation purposes. Specific contracts as follows:

(*a*) Upper Arkansas: Local contracting agency is Weather Research Association of southeast Colorado. Area includes Baca, Las Animas, Prowers, Brent, Otero, Kiowa, Cheyenne, Kit Carson, Lincoln, El Paso, Pueblo, Fremont, Custer, and Huerfano Counties. Original survey cost was $5,000. First contract covered July through September 1950, for $25,000. Second contract covered November 1950 through June 1951, for $22,500. Third contract under consideration for next summer.

(*b*) Northeast Colorado: Includes 8,000,000 acres along South Platte between Greeley and South Platte. Definite boundaries and contract price unknown.

(*c*) Northern Colorado: Includes Poudre, Thompson, and St. Vrain Drainage. Definite acreage and target boundaries unknown. Contract price about $15,000.

(*d*) Upper South Platte: Includes South Platte drainage above Denver. City of Denver included in local contracting agency. Acreage, boundaries, and price unknown.

(*e*) San Luis Valley. Presumably includes entire San Luis Valley. Acreage and contract price unknown.

(*f*) In addition, contracts are in negotiation stage in Grand Mesa area in Colorado and in Laramie, Albany, Platte, Converse, Niobrara, and Goshen Counties, Wyo. Newspaper reports indicate contract price will be 1.5 cents per acre in Wyoming.

State is compiling additional data. Will be furnished tomorrow if available.

VARNER, *Acting Assistant Regional Director.*

SACRAMENTO, CALIF., *March 13, 1951.*

To: Commissioner.
Subject: Artificial precipitation.

Information follows. City of Santa Barbara and Montecito County water district jointly have contracted with North American weather consultants, Eugene Bollay, president, of Pasadena, Calif. City and district operate their own silver iodide ground generators at times and locations directed by weather consultant. Target area is drainage area of Santa Ynez River above Juncal and Gibralter Dams, 219 square miles. Location target area southeastern corner Santa Barbara County. Contract price was $10,000 for the season with no guaranty of results. Southern Sierra Corp., Kern County, and Carrisa Corp. in Kern and Tulare Counties have contracted with Precipitation Control Inc., Phoenix, for various seeding flights, target area unknown. Contractor charges $122 per hour per plane. Southern Sierra Corp. contracted for 17 flights over drainage areas tributary to Tulare Lake in 1950.

BOKE.

Mr. STRAUS. One of the benefits that could come from this committee's endeavors would be requirement of the responsibility for securing and reporting on the many artificial precipitation operations that are going forward. It is only when such reporting is undertaken that prerequisite ground work and information is provided that will eventually permit establishment of respectable measurements by which the economic feasibility of various rain-making endeavors may be appraised. To a Bureau of Reclamation that must constantly consider not only the physical possibilities but also the economic feasibilities of water development and establish such feasibility, this is a primary essential.

In this testimony, I wish to defer to more competent witnesses on the scientific techniques of rain making which Reclamation accepts as an accomplished fact, although recognizing that techniques differ and improvements are not only possible but probable. Reclamation would like to place this new development in context for you in the Government water development and conservation program. In so

doing, I wish to remind the committee that the fight for good sweet water is getting fiercer, not only everywhere in the arid West, but throughout the rest of the country, including the East, as well as throughout the world. That is only natural as our drafts upon our good water supplies increase and as the availability of water proves itself each day the controlling point of agricultural and industrial development.

Each year we are using more water per capita. Water shortages are reported from areas once considered humid. Water use, in fact, may be accepted both as a measurement of domestic, industrial, and agricultural development, and even as a measurement of standard of living and civilization itself.

Agencies of the Federal Government, as well as local governments and private enterprise, have invested multiple billions in water development, not only in obtaining water, but also in flood-control works, industrial plants—including many of strategic value—municipal waterworks, and drainage facilities for protection of agriculture, transportation, railroads, highways, and a host of other capital investments.

All of these works, both existing and future, are at present designed on the basis of existing water supplies resulting from natural precipitation. The safety of towns and cities, the protection of transportation systems from floods, the power for industrial plants, and irrigation systems are all based on natural precipitation. Now there has been added an unknown of unnatural precipitation.

If the total precipitation in an area can be increased, as now seems an acceptable thesis under favorable conditions, many future designs of works for water utilization would have to be adjusted and some of the existing works might require modification at considerable expense. That would be true across the board, including the greatest waterworks of man, designed and built by the Bureau of Reclamation. Spillways may be larger, dams higher, canals and laterals wider and deeper. More land may be irrigated. More power may be generated. Of possible greater significance, fewer droughts may be experienced and the control by man of a significant portion of the rainfall may even so stabilize the water supplies in some areas as to reduce the need for costly irrigation works, and at the same time make available more water for needed power generation. Indeed, Reclamation's interest in this program and legislation is great.

I have been asked the question—I was asked it by a member of this committee yesterday—whether artificial precipitation might not put the Bureau of Reclamation out of business. I don't think that should be the criteria of your consideration. But, for information's sake, it is my belief that artificial precipitation and salt water conversion certainly would not put the Bureau of Reclamation out of business. It probably would increase our business although we strain to accomplish that which we have today.

Even the greatest optimistic artificial precipitation enthusiasts with whom I have talked have not yet advanced the thesis that artificial precipitation can or will assume the accuracy of precision pickle-barrel bombing so that raindrops can be released by aim on crops to be irrigated. Reclamation's primary irrigation business is collecting water wherever it may be and moving it to exact spots where it is needed—whether it comes from rainstorms, melting snows or glaciers,

rivers or lakes, or even underground supplies. I consider artificial precipitation in terms of another needed and welcome source of water supply—and a very valuable one—which supply as released should be collected and saved from where it might fall to the place where it might be needed.

Thus, the conservation and distribution of additional water that might be supplied by precipitation will impose upon all who deal with multiple-purpose river basin developments new tasks. One should consider that cropland in the West requires roughly about 3 acre-feet per year. In other words, rainfall of about 36 inches or more would be needed if no irrigation water were supplied, and in the more southern areas, such as Arizona, southern California, 40 to 50 inches of rainfall might be needed. The most optimistic estimates of commercial rain makers that I have heard place the maximum probable increase in precipitation that might be caused artificially—regardless as to whether that fell on predetermined fields—at about 100 to 150 percent of the natural rainfall, with perhaps higher amounts in the winter snow pack in the mountains. Thus in the areas of the West where the annual natural precipitation is in the order of 5 to 10 inches—and much Reclamation land would fall in this category—this increase of 4 or 5 inches would not be enough to sustain crop farming, even if happily dropped at the right time on just the right plants. It would, of course, improve the grasslands of the broad grazing areas immensely. Nevertheless, this additional water would still have to be impounded and distributed to lands where it is needed by what you have come to consider the normal Reclamation works. The run-off from the steep and rocky areas must be placed in the fertile valleys and passed through power plants even as is done today, but in greater volume with a new source of water supply. Flood-control works of today would have to accommodate the new quantities and much additional fertile land might be brought into production. The benefits which would accrue would be tremendous, and I am frankly disturbed at the realization that to date we have not yet developed a reliable yardstick by which we can at least estimate this increase in available water supplies that may be given to us.

With the water which may be made available as a result of salt water conversion, I am more optimistic because we shall at least be able to control its quantity and lay our plans accordingly. While this facet of the legislation before you will be productive, I feel sure, of considerable new fresh water near our sea coasts, and a quantity of sweetened water in our inland areas, all of which will require adjustment of our plans for water use, I do not believe that this problem will be as difficult of solution as those arising from modified hydrology of our Nation. Nevertheless in both branches of this endeavor to increase our total fresh-water supplies, we are met with a challenge to plan our waterworks now in such a way that they can accommodate the new quantities for the greatest benefit to the most people and at a minimum of cost.

That salt water conversion is physically possible nobody challenges. Only grandma's teakettle on the stove is required to prove this point. The problem is high volume and low cost of conversion of limitless sea water.

Several very promising methods for economically converting salt water have been investigated in one degree or another and it appears

that there may be some possibility that new methods not yet developed to maturity may prove of value in moving over the economic line. Compression distillation has been developed, I believe, near to its limit in plants of small size. By this I mean the largest plants developed by the Army and Navy for use abroad ship and on shore installations are small in size as compared with the needs of municipalities and irrigation interests.

For example, the largest compression distillation units under development in private industry on which we have been able to obtain knowledge would have capacities in the neighborhood of 20,000 gallons of fresh water per hour. While a battery of these units could be installed no doubt so as to produce possibly several million gallons of fresh water a day, even this amount is no greater than a large spring and would not supply a city like Los Angeles or New York or irrigation water in any appreciable amount. I visualize the construction, possibly, of a much larger compression distillation plant or modification thereof which in itself might attain much higher efficiencies than the smaller plants.

Another promising source of power which might be used in purifying water is the nearly untapped energy of the sun. Here again I wish to defer to better qualified technical witnesses, but I have no doubt but that the tremendous energy imparted by the sun can be harnessed not only for purifying sea water but for many other beneficial uses as well.

We are informed by research organizations of repute that there is great promise in the field of chemical methods for removing salt from water, and I believe that considerable basic research in this field is desirable to ascertain whether it may be useful for this purpose.

We are already aware that atomic energy reactor plants use large quantities of water for cooling purposes. This heat is wasted, and I am happy to learn that the Atomic Energy Commission is already investigating the feasibility of utilizing this waste heat for many purposes. But I am not informed that accurate economics on atomic energy are now publicly available.

We should not overlook the possibility that it may be possible to derive commercially valuable chemicals from sea water while extracting pure water at the same time. If this can be done on an economical basis, the revenue from the materials extracted might be used to reduce the cost of the fresh water, an item of major interest to irrigators. On the other hand, the chemical industry itself might find through this research that by producing fresh water as a byproduct of its primary purpose of extracting chemicals from the sea, the sale of the water could reduce the cost of the chemicals to the extent that production of fresh water might be attractive to private industry. It should be borne in mind in this regard that this research is not directed toward the production of fresh water—or chemicals—on a large scale but toward research and demonstration of means by which others—including private industry—could, if necessary, produce such water themselves.

Very real and practical considerations have confronted the Bureau of Reclamation in connection with artificial precipitation. We have received urgent requests from operating offices, one in El Paso and one in Boise, Idaho, for advice as to whether they should encourage or discourage the water users' association in contracting for commercial

rain-making services. We are, frankly, at a loss for an answer to these good people. Perhaps this legislation will provide the answers eventually. Today we dare not encourage them to spend their money on these activities, and we are not at liberty to discourage them from doing so. If additional water could be made available to them, we would be the first to want it, but we are fully aware that the average irrigation farmer has his normal expenses and cannot afford to be pouring money into a venture which he is not sure and positive will repay him.

Numerous water users' associations throughout the West have already contracted for such services and we view their situation as hazardous today. Nevertheless, I am not opposed to these operations and in fact believe that until it is shown by scientific research that such operations are causing any effect whatsoever and particularly any damage, we assume that they are—or should be—at least contributing something to the general knowledge of the subject. This contribution would be greatly enhanced, however, if these commercial cloud-seeding organizations could be required by Federal statute to install scientific measuring apparatus sufficient that analyses and evaluations of the results could be made by impartial organizations.

I wish to recommend all features of these bills to this committee which have to do with encouragement and measurement and appraisal of artificial precipitation and salt water conversion, and also repeat that the committee recognize the various proposed control systems as far-sighted legislative proposals and clearly an eventual necessity. I do, however, have a constitutional aversion to the supporting of mandatory control and regulating legislation and advising as to the language of such legislation until full information is available, measured, clarified, and appraised on the practices that are to be controlled. If detailed control legislation is provided by the Congress at this time, it must be on the basis of information at this time available. If better information becomes available to the Congress at a later date, you will undoubtedly have to reconsider any control legislation on the basis of information not now existent. In other words, to write the best controls into Federal law, we must first know all there is to know about what we are trying to control.

In closing my remarks, I believe that we should all recognize, first, that in the salt-water purification program and that of the artificial rainfall, we have a potential national asset which should be investigated rapidly and exhaustively; second, that the job is one for the Federal Government; third, that private and commercial organizations have a real place in both programs and should be encouraged, not discouraged; fourth, that we should lay the ground work now for instituting such controls as may be necessary, but that we should go slowly in instituting controls over processes about which we do not yet have information.

One matter that was discussed before this committee interested me, and that is just how such an operation can be set in motion, and I thought it might be helpful if we all recall a matter of a very parallel nature this committee considered a few years ago. I had the honor of bringing before this committee the synthetic liquid fuels program.

It was possibly in a more advanced state at that time than artificial precipitation is today. But there were many interests operating in it and with no clear information or licensing programs. The com-

mittee considered and evolved a program for unnatural, we will say, production of oil and for encouraging and assisting financially its development for producing synthetic liquid fuel from both coal and oil shale. That program became the responsibility of the Bureau of Mines, I believe, and has gone forward.

I thought, in considering what you were discussing before my testimony started, you might want to have that successful solution which this committee already evolved in your minds.

Are there any questions?

Senator ANDERSON. Thank you, Mr. Straus.

Mr. Bennett, we are going to be awfully tight here on time this morning. Can you go through your paper as rapidly as possible?

Senator CASE. I think that is a very constructive statement, Mr. Straus, and this suggestion that an effort be made to set up something at once, to get reports on all of these efforts is certainly helpful.

Senator ANDERSON. That is very desirable, and we are going to have to get that done, regardless of where the legislation finally places responsibility.

Senator SMATHERS. Mr. Chairman, may I ask this one question. Mr. Straus referred to the salt-water purification program. I assume that some of these witnesses who come along here will tell us about the progress of that particular program, will they not? Thus far, the emphasis has been on making rain, and I know it is a combined program, and I just wondered about that.

Senator ANDERSON. Secretary Chapman discussed the salt-water program at the beginning of his remarks.

Mr. BENNETT. I will get into that a little.

Senator ANDERSON. All right.

Senator SMATHERS. If we could—as to what progress is being made. Secretary Chapman mentioned it. You know that we have plenty of water down our way, but we have plenty of salt water, too much salt water, so we would be interested in that, too.

Senator ANDERSON. Also, on Monday, Dr. Sherwood and Mr. Fox, who are specialists in that field, will give testimony directly upon that.

Senator SMATHERS. Fine.

STATEMENT OF N. B. BENNETT, JR., ASSISTANT DIRECTOR OF PROJECT PLANNING, DEPARTMENT OF THE INTERIOR

Mr. BENNETT. Although Secretary Chapman, Assistant Secretary Warne, Commissioner Straus, and others have discussed the need for additional fresh water in the country, I feel that you might be interested in just a few actual figures of needs.

I have a chart on which there is shown the present water uses, the present water supply, and the future water requirement for each of the major subdivisions of the southwestern United States, together with a summary chart on the right showing the totals of the areas. These values are of course averages.

Senator CORDON. What do you mean by "future water requirements"? How far in the future?

Mr. BENNETT. The foreseeable requirement, as we see it now, potentialities existing today.

Senator CORDON. How long?

Mr. BENNETT. There are known places where water could be used today, if water were available.

Senator CORDON. You are speaking about the future water requirements; what do you mean by that?

Mr. BENNETT. There are sufficient lands available for irrigation; there are sufficient requirements for municipal water supplies that are known now to take those amounts of water.

Senator CORDON. Then, you mean future possibilities and not requirements. Requirements will be what people need.

Mr. BENNETT. Call it possibilities, if you will.

Senator CORDON. And, of course, that would vary with the number of people, and that probably would vary with the number of conditions, and certainly with the length of time, so you did not take the time element into consideration at all.

Mr. BENNETT. I will be happy to call it "future water possibilities."

Senator CORDON. Have you taken into consideration the time element?

Mr. BENNETT. We have, in terms of the municipal water, in attempting to forecast population growth.

Senator CORDON. How far did you go into the future?

Mr. BENNETT. We went about 50 years, in the municipal water, but that is a small part of the total. The biggest total for your potential uses is in the irrigation field.

Senator CORDON. You use that term "future," then, in the sense of all the future that may be, endless; is that right?

Mr. BENNETT. I do not quite see what you are driving at, Senator.

Senator CORDON. Well, a requirement to me is a necessity, and a necessity certainly requires some agency that needs, and the amount of that need is determinable in several ways and is limited by the time of the need, and unless you have made a study that indicates that within this area within a certain time the people who are here or who may be expected to be here will need so much water, I do not understand how you can guess into an indeterminable future and run that green line up as you have there.

Mr. BENNETT. Well, then, let us call it, there, if you will, "potential uses." Those are uses which could be made.

Senator CORDON. They are not requirements, I see. Now, we know what we are talking about.

Mr. BENNETT. The situation on the Rio Grande is not truly reflected by past averages. Serious water shortages have existed in recent years. This year, for example, March 1 snow-survey reports show water content of only some 50 percent of normal. The blocks in blue show the present consumptive use in each of those areas. The quantities shown in red represent the total natural water resources in those areas. The information at this time is of reconnaissance in nature, and the situation is not truly reflected on the Rio Grande by past averages. We have not yet completed our studies in the Rio Grande Basin. There are serious water shortages on the San Juan. That is one reason, you will notice on the map, the red line concentrates in that area. And, as I have mentioned, the snow-survey reports show a water content of only about 50 percent of normal in Rio Grande with the Pecos area running as low as 25 percent which, again, explains the concentration of your red there in the New Mexico area.

The blocks in blue show the present consumptive use of water in each of these areas. The quantities shown in red represent the total natural water resources in the same areas.

Senator CORDON. I take it that that means that the water is there. It does not mean that at the present time it is available for use.

Mr. BENNETT. That is correct; it is an average stream-flow figure.

The block shown in green is the total future water requirement for irrigation and municipal use to the extent that those requirements are known or can be forecast. It was derived by computing the amount of water required for present populations and for all known irrigable lands in the respective areas. In other words, the figures represent actual known potential uses and therefore may be somewhat less than the ultimate total if some additional irrigable lands are located.

In other words, our knowledge of uses advance much faster than our knowledge of sources.

Although the total water requirements shown in green on the chart are indeed impressive, an equally important message is given by the red and blue charts. Here we should pause to consider that in each case the present water use as shown in blue, now is approaching the total water supply shown in red. Particularly is this seen in the southern California coastal areas and the Rio Grande Basin. Here we are already using all of the local supplies and are importing water from the Owens and Colorado Rivers. That is in the south coastal area shown up in about the center of the chart. In the Lower Colorado River area the present uses comprise about three-fifths of the total supplies and in the Sevier-Bonneville and Lahontan Basin groups the present uses are approximately three-fourths of the total supplies.

Senator CORDON. May I ask you where that is geographically?

Mr. BENNETT. The map behind you, Senator, shows the area which corresponds to the charts. Your Sevier-Bonneville area is that upper right-hand area. Your Lahontan Basin, the Owens and Colorado Rivers are there.

Senator CASE. The Lower Colorado is obviously the largest except for the combination in Nevada and southern California. Does that mean that you are using all of the lands of the Lower Colorado Basin there in Arizona as known irrigable lands?

Mr. BENNETT. Those which we know at present are irrigable; yes, sir.

Senator ANDERSON. But the answer to his question is "No;" is it not? He asked if you were using all the lands in Arizona as irrigable lands.

Mr. BENNETT. Only those which are potentially——

Senator CASE. Those that have been surveyed and are irrigable from a topographical standpoint?

Mr. BENNETT. Right.

Senator CASE. Have you classified the soils?

Mr. BENNETT. As a soil survey? We have classified them according to our land classification method.

Senator CASE. Unfortunately, in my area we are running into a distressing situation.

Mr. BENNETT. I know you are.

Senator CASE. Where we started to build a project, and although the lands were irrigable from a topographical standpoint, they are telling us that salt and other problems raise the question of their irrigability.

Mr. BENNETT. That is correct, in your area.

Senator CASE. Has that kind of a test been made of all the lands that you have included here?

Mr. BENNETT. We have made, in practically all of these areas which are included, at least reconnaissance surveys, and in some of them we have covered them with detail surveys.

Senator ANDERSON. What do you show in the Lower Colorado potentially?

Mr. BENNETT. Present water use in the Lower Colorado at 5,000-000; potential at 31,00000,0—slightly in excess—31,250,000.

Senator ANDERSON. You have treaty obligations to deliver 9,500,-000 down there now, have you not—or 8,500,000?

Mr. BENNETT. There is a 1,500,000 obligation to Mexico.

Senator ANDERSON. I am not talking about Mexico.

Mr. BENNETT. Your obligation from the upper basin to the lower basin is 7,500,000 plus 1,000,000 for the Gila. That is why you notice that the middle one showed 8,500,000 feet allocated under the Colorado compact.

Since it is seldom feasible to put all water to use in an area, the present water uses approach the maximum feasibly available supply even more closely.

This chart showing the vast potential future water requirement should not be taken to indicate that we have hopes of supplying all, or even a large portion of that water by artificial means. Rather, if the supplies shown in red can be increased only slightly, the total available useful water will be increased sufficiently, we believe, to justify this program.

You will doubtless be interested in knowing what organization and procedures we feel necessary for accomplishing the research and demonstration and economic studies necessary under this legislation. Although the details cannot be worked out at this time, we have given considerable study to the general organization and plan of procedure.

The procedures which would be used in the physical research on salt water reclamation would, as you will recognize, be entirely different in the beginning from those relating to artificial precipitation. Later, however, the studies of the increased water supplies and their effects upon water-use plans, projects, and the economy must be tied together as the one supplements the other. The two, together with natural water supplies, will have to be considered as one undertaking. I shall discuss the research relating to sea water first, followed by that relating to artificial precipitation.

In sea water conversion research, it is expected that at least the first year will be devoted to the initial phase consisting of: (1) Exhaustive review and appraisal of all work accomplished in the past for the purpose of eliminating obviously unsound methods and to estimate the apparent economic potentialities of the remaining methods; (2) program of limited testing and planning for the improvement of existing methods appearing to have some promise of success; and (3) initial examination and probably design of experiments and research to be undertaken in the second phase.

Already it is possible to separate the several known methods into a tentative program, with at least some indication as to the public and private agencies which might be able to perform some of the research.

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We feel there should be an advisory board consisting of representatives of different interested agencies whose function will be to advise on the design of the actual program and to participate in the research through their agencies to the extent necessary. Secondly, consultants will be employed in each of the several fields such as compression distillation, solar energy, ionic exchange, marine thermal energy, and so forth, as the need for each arises. The function of these consultants will be to advise, review, and make recommendations on procedures and studies to be undertaken and to assist in appraising the results. Third, a planning staff consisting of a project director and his assistants who would comprise a planning staff to direct and coordinate all phases of investigations, to maintain liaison with cooperatively participating agencies, to give technical guidance to all operating units, to keep abreast of technical developments, to inventory the facilities of the various agencies and organizations, and to make recommendations as to the assignment of specific phases of the work to various agencies and organizations. Fourth, preliminary laboratory investigations will be conducted on known processes of salt water reclamation which have a possibility of economical feasibility and to explore new methods and possibilities. The aim of laboratory investigations is to eliminate those processes less worthy of larger scale study; and to obtain preliminary design and approximate cost data. Investigations would be conducted on the following:

(1) Solar distillation and solar power.
(2) Ion exchange.
(3) Marine thermal energy.
(4) Underground burning of coal.
(5) Electro-Osmosis.
(6) Utilization of waste heat from atomic energy.
(7) Other methods (requiring preliminary screening):
    Absorption of water.
    Freezing.
    Ultra sonic purification.
    Miscellaneous processes suggested by any contributor as program develops.

Fifth. studies will be made on possible pilot plant activities. This will be limited at present to contracts with private industry for design, operating cost data, cost estimates, etc., of large capacity thermal compression distillation apparatus and ion exchange unit. This should provide sufficient details for the construction of a plant available in the event of a potable water emergency, even though the studies would show that these processes could not compete with present sources of irrigation water. This part of the investigations would also include pilot studies on electrolytic methods and solar distillation methods, but to a more limited extent.

It is estimated that the work of this first phase will cost approximately $700,000 divided about 65 percent among Federal agencies and 35 percent among various private industries.

The second phase should consist of the construction of a so-called pilot or demonstration plant on commercial scales, at a location such as San Diego, Calif., and containing one or possibly more of the methods most promising. This latter phase cannot be spelled out in detail at this time as exactly what would be done would depend upon the results of the initial stage.

ARTIFICIAL PRECIPITATION

The outstanding need in artificial precipitation is for a yardstick by which to estimate the increase or decrease in precipitation that may be possible to cause artifically. Until this reliable yardstick is provided, the practical effects, which this artificial rainfall pattern will have, can only be approximated. We are fully aware of the studies of practical effects which should be made. For your information, I am including a list of them, which I will not take your time to read. You will note from the list, however, that the new science will affect almost every phase of water and land use.

The development of a satisfactory yardstick can be along two possible courses. I recommend that the two be pursued concurrently and immediately in view of the urgency and extent of the problems involved.

The first course is the formulation of an interim yardstick or criterion based upon the present available knowledge on the subject from which to make broad general estimates of this possible artificial increase in precipitation. This should be set high, at a maximum, and as research advances, the upper limit would be gradually reduced. It would also be on broad geographical basis at first, and could be more detailed, covering smaller areas, as research and field tests disclose the actual potentialities in a given area. Although these tentative criteria would prove to be too high at first, at least they will be an improvement over methods which we have today, and most importantly would permit us to begin evaluation of the economic effects almost at once. A selected group of the Nation's leading authorities on the subject would be called upon to make the best available estimate at present with full recognition that this undertaking would be subject to change and would be made only because of the urgency of the situation. This would be handled through the auspices of the American Meteorological Society, if possible.

The second course is to conduct the program of research from which the reliable and accurate facts necessary for making up this article can be ascertained. Simple as this may sound, it involves the whole range of physics of the atmosphere and all research is, in fact, directed toward this one goal. The physical research necessary to the development of a theoretical quantitative criterion is given in the attached outline appendix A. Some of this research is already underway, as you have been advised. The outline, therefore, represents the total deficiency in existing scientific data, and it would not be expected that there would be unnecessary duplication. Some duplication, however, is often desirable in research work in order to assure exhaustive probing of all possible results. In this regard we propose to let quite a large number of research contracts to universities, several of which should have the broad objective of exploring the general field without stringent restrictions. We find many brilliant young scientists in these institutions, working with almost no funds, who come up with new and sound explanations of weather phenomena that may escape the more mature and conservative weather researchers.

In addition to the development of this theoretical criteria, field tests of actual effects of cloud seeding are necessary to confirm or modify these criteria. This should be in two parts, first, statistical

evaluation of the results of commercial cloud seeding from existing records of precipitation and stream flow. It is recognized that such records in these areas are not often adequate for this purpose. In some cases they simply are not useful. But such of these studies as can be made must be made not only for this purpose but to solve many other problems, including some inevitable litigation. Compulsory reporting of cloud-seeding operations, and installation of additional records are needed.

The second, and far more reliable field measurements of effects of cloud seeding, will be in the nature of fully controlled tests. These tests must be designed to meet the requirements of a competent theoretical statistician, and field controls must be installed before the experiment is begun. Several such controlled experiments in different parts of the country are needed. I might add that the experiments made in the New York City watershed and those in the Owens River Valley in California are of the type needed. One complete test for areas in the Pacific Northwest was designed by the Bureau of Reclamation in January 1949. I regret that it has not been possible to conduct this and other similar tests from which you gentlemen might appraise the potentialities of this science and need for the research and controls you are now considering, and we might begin to reappraise the resource development programs of our country in accordance with the second outline which I have attached to this report. So far your attention has been directed only toward inducing rainfall. There are possibilities in certain areas of stopping, temporarily, precipitation on one side of a mountain range and thence inducing precipitation on the other side, thus helping to even up some unbalances.

APPENDIX A

RESEARCH NEEDS IN ARTIFICIAL PRECIPITATION

(List is designed to indicate all presently foreseeable research needs and includes research undertakings already underway and those not yet initiated.)

1. The determination of the physical processes involved in precipitation.
(*a*) From supercooled clouds.
(*b*) From clouds warmer than freezing.
(*c*) By other means.
2. The chemical composition of the atmosphere up to 30,000 feet or higher.
3. The influence of various chemical components upon precipitation.
(*a*) Influence upon the activity of nucleating substances.
(*b*) Influence upon precipitation static.
(*c*) Effect upon coalescence, sublimation, and condensation.
4. The effect of sunlight upon nucleating substances and upon the formation of precipitation.
5. The time-duration effectiveness of silver iodide and other nucleating agents.
6. Developments of new types of nucleating agents and means of controlling their life and activity.
7. A study of nucleating agents present naturally in the atmosphere, the nature and sources thereof.
8. The development of improved means of counting and identifying nuclei and nucleating agents in the atmosphere.
9. The extent and rate of travel and dispersion of nucleating agents.
10. The use of dry ice by other means than from airplanes.
11. Determination of the effects which artificial nucleation may have upon:
(*a*) Rainfall in adjacent local areas.
(*b*) Weather and climate of extensive portions of the Nation.
(*c*) Weather and climate of the entire Northern Hemisphere.
12. Means of deactivating artificial and natural nucleating agents present in the atmosphere.
13. Optimum quantities of artificial nucleation under various physical and chemical atmospheric conditions to (1) produce maximum precipitation; (2) to

insure against "overseeding" resulting in reduced precipitation; (3) to cause "overseeding" where desirable.

14. Means of artificially inducing the formation of clouds from humid atmosphere.

15. The development of more satisfactory criteria to determine the maximum increase in precipitation that may be possible artificially.

APPENDIX B

OUTLINE OF STUDIES OF PROBABLE EFFECTS OF ARTIFICIAL PRECIPITATION

I. CHANGES IN WATER SUPPLIES

A. In streams:
   1. Quantities and rates.
   2. Season and frequency of occurrence.
   3. Quality (initially increased erosion from formerly arid lands). (Reduced erosion eventually from increased grass cover.)

B. Underground supplies.

C. On croplands direct:
   1. Quantities and rates.
   2. Season and frequency.
   3. Subsurface storage in soil.

II. STUDY OF EFFECTS OF CHANGED WATER SUPPLIES ON WATER-USE AND CONTROL PROJECTS

A. Existing projects:
   1. Revision of operation schedules using existing facilities only:
      (*a*) Irrigation.
      (*b*) Power.
      (*c*) Flood-control works.
      (*d*) Other.
   2. Alteration of existing facilities:
      (*a*) Dams and reservoirs, spillways, storage capacities, power plants, additional reservoirs, flood-control works.
      (*b*) Distribution and transmission systems.
      (*c*) New lands made irrigable by I–A and B.
   3. Increased direct rainfall on cropland and grazing lands (result of I–C).
      (*a*) Reduction of irrigation demands on existing lands.
      (*b*) Use of excess resulting from (*a*) on new lands.
      (*c*) Changes in class of crops.
      (*d*) Effects on soil moisture supplies.
      (*e*) Additional drainage problems.
   4. Erosion and sedimentation:
      (*a*) Lands.
      (*b*) Channels.
      (*c*) Canals.
      (*d*) Reservoirs.
   5. Effect on parks and on fish and game.

B. Revised basin plans:
   1. Altered diversion demands due to reduced crop demands.
   2. Altered storage requirements.
   3. Altered spillway requirements.
   4. New reservoir sites made feasible by new water supplies.
   5. Alterations in replacement plans.
   6. Changed firm and secondary power sources.
   7. Additional drainage problems.
   8. Effect on seasonal water variations and on planned for water shortages.
   9. Effect on total water supply.

III. RELIEF OF SEASONAL DROUGHT IN SOUTHEAST UNITED STATES

A. Increased rainfall on croplands:
   1. Changes in class of crops.
   2. Increased yields of present crops.

B. Stabilized stream flow and ground water:
   1. Increased power production.
   2. Improved water supplies and sanitation.

C. Altered drainage and water disposal requirements.

D. Adjustments in local industry and economy.

IV. INCREASED WATER SUPPLIES FOR EASTERN CITIES

A. Revision of storage operation schedules.
   1. Municipal supplies.
   2. Power.
B. Alteration of existing facilities.
   1. Dams, reservoirs, spillways, distribution systems.
C. Reduced need for storage works.
D. Effect on ground water.
E. Effect on navigation.

V. MISCELLANEOUS EFFECTS

A. Increased snow removal; effect on transportation; costs; costs versus benefits.
B. Increased runoff and floods.
C. Erosion.
   1. Increased by increased run off.
   2. Decreased by improved vegetation.
D. Potential reduction of forest fires.
E. Potential reduction or increase in hail damages.

VI. CHANGED CLIMATE—LOCAL, NATIONAL, GLOBAL

This study which may be more far reaching than all others cannot be specifically outlined until considerable research work is advanced under "Procedure I-II."

Mr. BENNETT. I would like to raise two aspects of artificial precipitation which have not been turned upon to my knowledge. One is the possibility of not causing precipitation, which you have dwelled upon, but rather of stopping it in certain areas for limited time while that particular cloud body moves over a mountain, for example, and then is caused to drop on another area.

For example, in the far Pacific Northwest along the Puget Sound area where you have tremendous rainfall on the west side of the Cascades which falls and runs through very short streams right into Puget Sound serving only a power purpose, if that rainfall, or some of it, could be kept from falling there, could come over the mountains and fall on the other side, it would be a tremendous help.

Senator ANDERSON. Incidentally, Dr. Schaefer has discussed that very possibility, privately, at least, and it is a strong possibility of dividing up the rainfall where it is excessive in one area and insufficient in another.

Mr. BENNETT. I am glad he has done that.

One other aspect about which we know probably nothing is the possibility of utilizing a similar method for air-pollution control which is a problem in many large cities. That should be looked into also.

Senator CASE. To get away from smog?

Mr. BENNETT. Yes, sir; Los Angeles, Pittsburgh—any of those areas which have an air-pollution problem.

Senator SMATHERS. It is a matter of record, I see.

Mr. BENNETT. With that, I will be happy to close, Mr. Chairman.

Senator ANDERSON. Thank you, Mr. Bennett. I think the possibility you make of keeping the cloud and seeing that it does not precipitate on the west coast where it is not needed and go across a mountain range and fall on an area where it may be needed is the hope we all have somewhere in the program.

Senator SMATHERS. You have to figure out how to guide that cloud sooner or later, to put a rudder on it, which, also, may have possibilities.

Senator ANDERSON. There are definitely established wind patterns.

Thank you, Mr. Bennett. Mr. Lineweaver.

STATEMENT OF GOODRICH W. LINEWEAVER, ASSISTANT COMMISSIONER, BUREAU OF RECLAMATION

Mr. LINEWEAVER. Mr. Chairman, I desire to submit reports from the Department of Agriculture, the Department of State, Department of Defense, Department of Commerce, Public Health Service, and General Services Administration which were originally prepared last year and sent to me as Chairman of the Interdepartmental Committee that was established by Secretary Chapman to consider legislation under S. 1300 and H. R. 3123 in the Eighty-first Congress, and which were reaffirmed with respect to S. 5 by representatives of these departments at a meeting last Friday. The reports from Agriculture and Commerce deal only with salt-water conversion.

Senator ANDERSON. We have included some of the reports in the record already.

Mr. LINEWEAVER. There may be some duplication, but some of them have not been included.

Senator ANDERSON. Thank you very much. They will be included in the record.

(The reports referred to are as follows:)

STATEMENT OF THE DEPARTMENT OF AGRICULTURE

The Department of Agriculture endorses this bill because we believe it offers possibilities of affording important benefits to the people of this country. While we cannot predict all the potential benefits, it is apparent that a cheap process for converting salt water to fresh in large quantities might free our large seaboard population centers from dependence on limited water supplies transported overland. It is conceivable that with cheap, dependable, and unlimited water supply from the sea, some of these cities could release considerable quantities of water now moved overland, for use in irrigating productive soils now lacking a water supply. Furthermore, some of this released water might be delivered to areas close to large population centers, through existing conduits, to use in producing crops for these urban markets, thereby saving transportation costs.

A cheap process might also offer prospect of irrigating land at feasible transportation distance from tidewater at less cost than would be required for the development of areas necessitating expensive storage and long overland movement of water. To have such a process available would fully justify efforts to develop it for future use.

It is also possible that experiments to develop a cheap process of salt-water conversion might disclose possible ways of desalinizing some of our stream and ground-water supplies so as to overcome the difficulties in using them for irrigation.

While these direct benefits to agriculture may be overshadowed by those to domestic and industrial users of water, and to the Nation through having stand-by sources of supply in case of war, the combined potentialities of the undertaking justify the effort.

EXCERPT FROM LETTER FROM THE DEPARTMENT OF STATE TO THE SECRETARY OF THE INTERIOR DATED MAY 8, 1950

The Secretary of the Interior has pointed out the extreme importance of this program as it relates to our natural resources and national defense. In addition, the Department feels that as soon as economically feasible processes are developed they will be valuable in connection with our relationships with friendly nations. They will be valuable contributions to the administration of policies which depend on ample crop production, which promote the interchange of scientific and technical information, and which arise under treaty obligations in respect to border water allocations and pollution. This know-how will aid in the Department's present technical cooperation efforts, and also in the expansion of such efforts if

pending legislation concerning technical cooperation is enacted, particularly as many of the underdeveloped areas of the world are arid or face water shortage problems.

Sincerely yours,

JOHN E. O'GARA,
Deputy Assistant Secretary for Economic Affairs
(For the Acting Secretary of State).

STATEMENT BY DR. HELMUT E. LANDSBERG, PREPARED FOR PRESENTATION BEFORE THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS, UNITED STATES SENATE, ON S. 1300, A BILL TO CONSERVE AND INCREASE THE NATION'S WATER RESOURCES

My name is Helmut E. Landsberg. I am executive director of the Committee on Geophysics and Geography of the Research and Development Board, Department of Defense.

The Department of Defense favors the enactment of Senate bill 1300, Eighty-first Congress. The bill deals with research and development designed to lead to an increase of the water supply of the Nation. Water for beneficial consumptive use is one of the most strategic materials.

An adequate supply of water of satisfactory quality is essential not only for the peacetime economy of the country but also for waging a modern war successfully. Without sufficient water supplies cities and concentrations of population cannot exist; industry cannot produce the needed materials and equipment, and agriculture cannot meet the requirements for food production.

The installations, facilities, and manufacturing establishments operated by the Department of Defense consume water in large quantities.

The means of modern warfare also endanger water-supply systems. Reservoirs and dams are exposed to overt or covert enemy action. Surprise attacks can be expected in any future war. They may include attempts to contaminate the water supplies of the country.

At present the water supplies of the Department of Defense installations are mainly drawn from ground-water and surface sources. In a few cases where such supplies are inadequate, artificial means of producing the necessary water have to be resorted to. The installations of the Department of Defense use, wherever possible, water systems owned by private business or municipalities. Approximately one-half of the present consumption of these installations is purchased from such sources. In some cases, of course, Government-owned facilities have to be developed and operated.

In the event of a national emergency, large amounts of additional water supplies will be needed. A consideration of the water uses of various nations shows a close relation between industrial and agricultural productivity and the use of water. The United States, which in this respect leads the world, uses by far the most water. The more backward a country, the less water it uses, and in the least developed areas water is only used for drinking, cooking, and primitive sanitation.

A few decades ago a supply of 100 gallons of water per capita per day was considered ample. Now more than 200 gallons per capita per day, for municipal and purchased industrial and commercial use, are not out of the ordinary.

During the last two wars, although the water resources of the United States were greatly strained at times, the Nation was fortunate in having adequate rainfall replenish its supplies. Had the shortages of rainfall that characterized the decade of the thirties coincided with the peak water demand of the war facilities, the war effort would have been seriously handicapped.

Until rather recently, water supply was generally taken for granted and, as recently as the opening stages of World War II, construction of military camps or industrial facilities were commonly well advanced before consideration was given to the potential sources of water. More than 300 potential sites for war facilities had to be abandoned or plans had to be severely modified because water supply was found to be insufficient or unsuitable.

The most serious aspect of the water supply problem is the increased requirement for industrial use that has to be anticipated for an emergency period. These requirements run into the billions and even trillions of gallons per year for some of the most critical war production industries. To enumerate but a few, these include steel, oil refining, paper pulp, synthetic rubber, aluminum, airplane engines, industrial alcohol, cotton mill textiles. At the peak of production during

World War II, the steel industry required, for example, 1,800,000,000,000 gallons of water per year; oil refining at the same time used 1,400,000,000,000 gallons of water per year. The other industries required somewhat less but still the figures are astronomical.

In a future war the requirements are likely to be stepped up even beyond the enormous values quoted. At the present time, that is, in 1950 we consumed in this country for all industrial operations, steam generation for electric power, and railroads as much as we consumed during the peak of World War II, namely, around 29 trillion gallons per year. It is estimated that at the peak of a possible war that might occur in the next few years, the annual requirements for these uses will rise to 42 trillion gallons. That is an increase of about 20 percent beyond the total present uses of water for all purposes, including agricultural, industrial, steam power, domestic consumption.

The possibility to have to supply this water during a period of drought years looms as a sinister specter that might weaken the Nation's strategic potential seriously. Any effort to create by appropriate research and engineering development additional water supplies is, therefore, in the interest of national security.

The agencies of the Department of Defense have been confronted with the problem of water shortages in many phases of operation. They range from keeping individual sailors, soldiers, and airmen alive on drifting rafts and lifeboats, to the supply of fresh water on ships and submarines, to furnishing water to large bodies of troops in dry regions and for isolated strategic stands and bases for which local water supplies were inadequate. The solution of these problems required considerable research and development work. While the work on these specialized aspects continues, it can be stated that solutions have been found. The majority center around the production of pure water from salt or sea water. Many scientifically possible avenues were explored including certain chemical methods. These proved to be far too costly to produce fresh water from sea water. The only practical method for large scale sea water conversion has been the distillation method.

The solutions now at hand are not on a competitive, economical scale but when water is needed to sustain life of our fighting men, to increase the cruising range of our ships, or to occupy strategic positions, the factor of cost is not the most important one. However, the know-how acquired in this research and development work would form an excellent basis from which to start the work envisaged by S. 1300. All the information on this subject now on hand in agencies of the Department of Defense would, of course, be made available to the Department of the Interior should they embark on this work under the authority to be given by this legislation.

Let me summarize briefly for you what has been accomplished. The Department of the Navy, for example, has for over 40 years been manufacturing its own sterile, potable, fresh water aboard Navy vessels by the distillation of sea water. This water is used for drinking purposes, for boiler feed, and storage battery make-up, as well as for laundry and cooking. Distillation aboard naval vessels is accomplished either by low-pressure steam or vapor-compression distilling plants developed by the Navy in 1937. They have capacities up to 2,000 gallons per day. These require cleaning at intervals from 250 to 500 hours of operation because of rapidly forming scale deposits. Large vessels, driven by steam turbines, have been equipped with low-pressure steam distilling plants with capacities ranging from 4,000 to 40,000 gallons per day.

These operate on surplus of auxiliary exhaust steam. The heat of this steam would otherwise be wasted and the distilling units are superior from the points of view of weight, space, efficiency, and maintenance.

The Department of the Navy is now proceeding with the development of a high-capacity distilling plant under contract with the Bethlehem Steel Corp. This design will eliminate some of the cleaning problems and the large vapor pipelines required by previous designs. Other research work in progress aims at reducing the scale formation on the tube surfaces of the installations needed for Diesel-driven vessels in order to enable the distilling units to operate for sustained periods at maximum capacities. Much of this research is, of course, peculiar to the problems encountered in shipboard use.

The Department of the Army, through the Corps of Engineers, under the exigencies of World War II also had to carry on development work on producing potable water from sea water. The global aspects of the conflict led to fighting and logistical operations in areas of the world where fresh water was not existent in sufficient quantities. The major requirements were for distilling units that were readily portable. In this development work, too, the conclusion was that the

distillation process offered the only approach that would satisfy the military requirements. Originally equipment with a capacity of 1,000 gallons of water per day was developed, consisting of one evaporator and one condenser. Later double and triple effect units were developed. In the multiple effect equipment the latent heat of steam from the first evaporator is used to boil additional sea water in a second evaporator and this is repeated for additional evaporators in the system. The addition of second and third evaporators increased the efficiency of the distillation process. To keep the equipment portable this was the limit of practicability for Army use.

Stationary equipment of larger type for land installations have also been built, based on the vapor compression principle. On June 1, 1950, such a plant will start service testing by the Corps of Engineers at Kindley Air Force Base near Hamilton, Bermuda. This will have a capacity of bout 30,000 gallons per day. The estimated cost at current fuel prices will be about $1.50 per 1,000 gallons of water. Further units planned for development by the Army include portable types of up to 7,200 gallons per day and up to 100,000 gallons per day for stationary units.

The original equipment was quite inefficient. It used 1 pound of fuel for every 12 pounds of water produced. At the present time an efficiency of 200 to 1 can be readily anticipated, i. e., for each pound of fuel burned 200 pounds of water will be produced. This roughly seventeenfold increase of efficiency is the result of just a few years of research and development work. The research work contemplated under the pending legislation S. 1300, which would not be hampered by limitations inherent in the military and naval use, might very well lead to even more economical solutions. The vapor compression system has not yet been driven to its ultimate possibilities. For example, it might be combined in some areas with high vacuum distilling units and that may reduce costs very considerably.

For large land-based installations it would, from current experience, seem quite feasible to incorporate large distilling units with existing facilities at steam power plants. It is estimated that the latent heat now wastefully discharged from such plants could be used to produce about 5 pounds of water per pound of turbine exhaust steam. Such combination plants would bring fresh water production from sea water much closer to an economically attractive range.

In brief, the research experience in the Department of Defense leads to the conclusion that production of potable water is technically feasible and future work may well make it economically attractive. This work should be undertaken in peacetime. It would not only be of large potential benefit for the conservation of limited natural water resources in the civilian economy but also might become an invaluable asset in a time of war.

With respect to the production of water from the atmosphere, especially from clouds, no such positive statements can be made at this time. In this field we are still in the phase of basic studies on the physics of clouds. We are still trying to wrest some of the secrets from nature. The processes of rain formation—and one step removed rain making—are beset with a great many unanswered questions. Many of these answers are still in the controversial stage. There is no conclusive evidence as yet that we can pin any hopes on producing at will economically important amounts of water by presently known techniques. One of the major difficulties is that even under the best circumstances, rain might possibly be induced if nature provides the moisture and forms the clouds. In cases of drought conditions, when the water problem is really critical, the skies may remain cloudless for days on end. Basic research into the physics of clouds is very important for several reasons beyond that of making rain. As a byproduct of this research, new knowledge may be gained to throw some light on the open questions, nevertheless, there is some hope on the basis of present knowledge that, under favorable circumstances, precipitation may be induced from clouds in as yet unknown quantities.

Statement by the Secretary of Commerce

There is a very widespread opinion that industrial consumption of water is minor in relation to public use. This opinion is substantially incorrect, and is probably one of the reasons for the insufficient awareness in the public mind of some of the factors which are presently believed to cause the Nation's insufficient water supply.

A glance at just one industry—the petroleum industry, will show how fallacious this opinion is. For example, the Baton Rouge refinery in Louisiana, although it

consists of only one plant, uses more water than the city of Cleveland. The Bay Way refinery in New York in turn uses more water than the city of Buffalo. The pumps at Baton Rouge send water through their cooling towers at an average rate of approximately 260 million gallons per day. In spite of the fact that the refinery makes every possible effort to restore the water it uses to its original source, it must add about 13 million gallons per day to its system to make up for the loss caused by evaporation, leakage, and spray.

As a matter of fact wherever water is used for cooling in industry there is always a certain amount of loss. Petroleum experts estimate that 23 gallons of water must be used to refine 1 gallon of gasoline. Since approximately 24 billion gallons of gasoline are produced each year the petroleum industry must have available to it about 552 billion gallons of water each year. Some 3 percent of this amount is unrecoverable with the result that about 17 billion gallons of water are lost each year in the production of gasoline alone.

These figures are not in any sense to be taken as a condemnation of the petroleum industry; as a matter of fact that industry is known to operate on a very sound technological basis. Rather they are offered to indicate that an industry, in order to operate in a given locality, must not only be assured of a large initial water supply but must also be certain that there is enough water to replace what is lost each year.

As a matter of fact, particular attention should be focused on newer industries and plants since they are not as likely to be restricted by existing plant design and knowhow as are the older ones. While, for example, 23 gallons of water per gallon of gasoline may seem relatively high, the plant now under construction at Brownsville, Tex., for the synthesis of gasoline and other products from natural gas will very likely require some 377 gallons of water per gallon of finished product. In the rubber industry it is estimated that 160 gallons of water are needed in the production of 1 pound of butadiene, and in the case of the rayon industry 100 gallons of water are required in order to produce 1 pound of viscose rayon.

Other large industrial users of water include the steel industry, about 36 gallons to 1 pound of steel; the smokeless powder industry, about 25 gallons to 1 pound of smokeless powder; the paper industry, about 26 gallons per pound of paper; the sugar industry, 10 to 14 gallons for each pound of refined sugar; and the textile industry which required about 47 gallons for each pound of finished textile product.

It should be noted that where water is used primarily as a cooling agent, as is the case in the petroleum industry, not only may impure or salt water be used to a large extent, but the amount of water lost is relatively small. Thus the Bay Way refinery in New York satisfies 97 percent of its requirements by the use of sea water. However, the remaining 3 percent, or about 7.8 million gallons a day, is required to be fresh water. As has already been pointed out, of the amount of water used each day only about 3 percent is unrecoverable.

However, where water is used as an inherent part of the process of manufacture in the vast majority of cases only fresh water can be used, and the amount lost is considerably in excess of the 3 percent figure cited in the case of the petroleum industry unless special processes are used to repurify the water. The paper industry, for example, must replace or purify each day almost all the water it uses because in the course of the manufacturing process the water becomes impure. The same comment is equally applicable to the textile and dye industries, to the leather industry, and to all other industries which employ fresh water in a manner which requires the addition thereto of chemicals and other matter.

It is important to remember that in the normal manufacturing process not only is a large amount of water made unrecoverable but also that the return of the used impure water to its source may have the effect of rendering unusable a large additional amount of water. We have all long been aware of the problems created by the establishment of a manufacturing plant on a river or stream with the result that the water becomes polluted and unusable by those situated downstream from the plant.

The conclusion is obvious: No area of the country can hope to attract new industries unless it can point to a steady easily procurable supply of fresh water. No new plant is constructed or an older plant enlarged without a detailed preliminary investigation by designers and engineers to determine the accessibility of a satisfactory water supply. As a consequence, many areas can have no hope of increased activity until they can furnish industry with the needed water. Other areas which formerly had an adequate water supply are now becoming

alarmed over dropping water tables as the supply of ground water decreases. An increasing source of trouble, moreover, is the fact that in the areas adjacent to salt water falling water tables tend to bring about infiltration of salt water, thus partially salinating the water already there.

There can be no question that the enactment of this bill might afford a solution to the problems created by an inadequate water supply. Enough advances have been made in the field of converting salt water to water which is usable for many purposes to indicate that further research may well reveal an economical method for utilizing the vast water resources which surround this country. We, therefore, urge the enactment of this bill so that the vital research needed may go forward at once.

STATEMENT BY WILLIAM E. HOLY, DIVISION OF SANITATION, PUBLIC HEALTH SERVICE, FEDERAL SECURITY AGENCY

1. Severe droughts in the past have introduced serious public health hazards in certain areas of this country owing to deficiencies in public water supply. The availability of an abundant supply of safe water would have averted the illnesses and inconveniences that resulted from the droughts.

2. The availability of equipment that could produce an abundant supply of potable water from saline water would be a safeguard of tremendous importance during an acute emergency such as might occur during a war.

3. Experience of the Public Health Service in the observation of distillation equipment on board vessels shows that such equipment may be relied on to furnish safe water under most operating conditions. Limited experiments carried on by the Public Health Service at Quincy, Mass., further demonstrated this reliability in a satisfactory way.

STATEMENT BY P. F. SEWARD, COMMISSIONER, COMMUNITY FACILITIES SERVICE, GENERAL SERVICES ADMINISTRATION (SUBSEQUENTLY HOUSING AND HOME FINANCE AGENCY)

This agency has been in close contact with the water needs of communities for the past 16 years. In the period of 1940–46, operating as Defense Public Works and War Public Works for the express purpose of correcting deficiencies in essential facilities which would hamper the war effort, the organization was required to provide water for both civilian and industrial use by any means. The rapid expansion of industry and contingent communities exposed the deficiencies in water supply in a most abrupt manner.

The normal expansion and improvement programs of nearly all of the larger communities contemplated a gradual increase in water demands; however, the acceleration of production due to defense and war demands brought water problems, that would normally require 20 years for accomplishment, into immediate view. This increased demand was not due entirely to accelerated production and the resulting concentration of people; new processes, new types of machines required enormous amounts of operating, washing, and cooling water. The demands for process water rapidly depreciated the potable water supply or caused radical changes in distribution patterns. Where the supply of clean water was limited by source restrictions or treatment plant capacities it was found expedient and effective to provide untreated water for industrial use if not unsuitable for the manufacturing processes. This might be classed as a conservancy measure.

The demand thus developed by the combination of circumstances above described has not decreased greatly. Many of the production processes developed during the war period are in common use today in all kinds of manufacturing plants. Many communities that depend entirely upon specialized activities such as mining, agriculture, oil production, etc., have found that to balance the economy of the area, industry of an appropriate kind is needed. The sufficiency of the water supply is one of the first questions asked by prospective investors and it is frequently found to be deficient for a desired purpose.

In the arid and semiarid lands the need for fresh water in quantity is uppermost. Since the beginning of history men have sought a practical means of converting salt or chemically charged water into a potable or fresh water at a cost that they could afford to pay. We have conducted experiments in solar distillation of salt water in the Tropics for the purpose of ascertaining the feasibility of that process under field conditions. The record indicates that potable water may be obtained by this method under certain climatic conditions, particularly

in arid or semiarid areas where no other dependable source exists. This small-scale experiment was discontinued after a period of about 3 months due to lack of funds to continue the work. This method of water production should be given all of the effort necessary to either accomplish the desired result or to prove the impossibility of practical accomplishment.

The basic factor in the potable-water problem is the source of such water. The transportation and distribution is a problem of mathematics that can be solved by comparative studies and estimates. Treatment processes are such that the reuse of water by disinfection and clarification can be given thoughtful consideration. This again may be classed as conservation rather than development; however, the purpose of new sources of potable water is to maintain a balance between supply and demand of the most important element in life on earth. Studies in conservation must go hand in hand with basic source development.

Senator ANDERSON. Mr. McKinney?

STATEMENT OF ROBERT McKINNEY, CHAIRMAN, NEW MEXICO ECONOMIC DEVELOPMENT COMMISSION, SANTA FE, N. MEX.

Mr. MCKINNEY. My name is Robert McKinney. I am here as chairman of the New Mexico Economic Development Commission. We happen to be right on the firing line of rain making, and I think we may be able to report on some phases of the subject that you may not get from other sources.

In New Mexico and other parts of the arid Southwest, the need for the legislation proposed in Senate bill 222, Weather Control Act of 1951, is urgent and vital. The need is equally urgent, whether it eventually proves to be possible or impossible to adapt rain-making techniques to practical, widespread commercial use.

Eminent scientists have testified as to their belief that rain-making techniques can induce or increase rainfall in significant amounts. We hope and pray that they are right.

Successful commercial application of rain-making techniques, however, requires that rain be induced at the place desired, at the time desired, and in the amounts desired. Moreover, this must be accomplished without undue danger to property or the public safety.

In New Mexico, rain-making experiments have been carried on by the research laboratory of the State school of mines for the past 2 years, under contract to the New Mexico Economic Development Commission for which I speak today. Our scientists have not devoted their studies to the long-range or long-distance effects of weather control, but rather have been making a basic study of local effects as they may be produced by laboratory techniques in what might be termed large-scale, outdoor trial runs. Our school of mines scientists have made numerous attempts at rain making. In a few instances they are reasonably confident that they induced rain, or increased the precipitation which would have occurred naturally.

The purpose of my appearance here is to urge immediate enactment of the Federal Weather Control Act of 1951 from the standpoint of the public interest.

Regardless of whether it is yet feasible and wise to attempt rain making on a commercial scale, there are only two possible alternatives: either it is possible for man to control the weather and make rain at his own will, or it is not possible to do so.

If it is possible to regulate the weather, man's first attempts at taming it may be as dangerous to life and limb as the first efforts of tenderfoot horsebreakers at breaking wild horses. Three of the

storms which occurred in New Mexico at times when our school of mines scientists were engaged in rain-making activities were accompanied by floods and property damage. If there is any coincidence between attempts to make rain and rain itself, similar instances may be expected in the future, perhaps increased in ratios of fantastic scale by the ever-increasing number of rain makers who enter the field daily.

The public welfare and public safety, interstate commerce, and common defense provisions of the Federal Constitution necessitate Federal regulation of such activities.

Now, on the other hand, let us assume that it ultimately be proved that rain-making techniques cannot be applied commercially with any degree of practical success. In that event, only Federal regulation can prevent unprincipled individuals from mulcting the public by representing that they can control the weather when in fact they cannot.

There exist in New Mexico today, or are being negotiated at this time, contracts with commercial rain-making firms virtually blanketing the State. The same is true of many of our neighboring States.

This is, of course, due to our prolonged and serious drought. Naturally, our people are desperately seeking for any remedy. They, like any seriously ill person, are willing to try anything which offers hope for relief.

Nor can they be blamed for this, in view of their lack of knowledge concerning the limitations of cloud modification techniques at their present stage of development. Commercial rain makers, therefore, whether they be properly qualified or not, are literally making hay while the sun shines and the rains do not come. From what we hear, the sales methods of a few may be reminiscent of the snake-oil barkers and the lightning-rod salesmen of our childhood. I have seen recommendations that "our artificial hail is mushy and will not hurt your crop; our artificial rains are general and will not erode your soil." I do not wish to imply that all commercial operators are deliberately faking, but I do wish to point out that no controls whatever exist to keep fakers from operating in this field.

Rain-making contracts are often cleverly drawn. They guarantee nothing in tangible results. Yet thousands of dollars are being paid commercial rain makers in advance by drought-panicked farmers and ranchers. Additional payments are stipulated according to volume of precipitation during the contract period. The rain maker takes no risk. He has his in advance. Should there be more than average normal precipitation, even though it results from natural causes, the rain maker collects enormous added fees.

Senator ANDERSON. Did you hear me this morning when I mentioned that, in southwest New Mexico, they signed a contract one day and it rained that night.

Mr. MCKINNEY. And, Senator, the bonus in one contract for more than normal rainfall runs up as high as $50,000 in one small group of counties. Furthermore the observations by the New Mexico School of Mines show that although there was heavy rainfall in areas where the rain makers worked last summer, it also shows conclusively there was an equal amount, perhaps even more, of normal rainfall in other areas where the rain makers were not operating and could not possibly have had any effect.

From a sales standpoint, commercial rain makers operate in interstate commerce just as surely as do the stock-and-bond salesmen now regulated by the Securities and Exchange Commission.

From an operating standpoint, the commercial rain makers operate in interstate commerce just as surely as do radio, telephone, telegraph, aviation, and other similar federally regulated interstate enterprises. The fact that the Weather Bureau is a Federal agency, not a State function, is ample proof that the Congress long ago recognized the weather is interstate.

Rainstorms, floods, and drought are no respecters of State lines. Attempts to control the weather, or to sell purported weather controls, cannot and will not stop at State lines. The responsibility for damage to life and property, the responsibility for fair representation of the cost and worth of the services sought to be sold must be recognized as an interstate responsibility. It is even international in scope, since 17 of our States border on foreign countries.

Evidence is accumulating daily which indicates a concerted plan on the part of special interests to avoid legal responsibility for their actions in this field. In New Mexico, for instance, the following bill was introduced in the recent session of the legislature by a group of cattle growers:

> The study and analysis of annual precipitation and general weather conditions and the attempted increase of annual precipitation are hereby declared to be beneficial and in the public interest, and the purpose of studying and analyzing such annual precipitation and general weather conditions and attempting to increase the annual precipitation is hereby declared to be a benevolent, charitable, and scientific purpose.

I am quoting from the statute, gentlemen. I would laugh, too, if I were not compelled to weep, because I live in this State.

> Incorporators desiring to form a nonprofit corporation for the purpose of studying and analyzing annual precipitation and general weather conditions and attempting to increase the annual precipitation may incorporate such corporation as a corporation for benevolent, charitable, and scientific purposes pursuant to the provisions of section 54–1306 to 54–1310, New Mexico Statutes 1941.

That may be the beginning of a fiasco.

The effect of such a law will be that the incorporators cannot be held legally responsible for any damage which may result from attempted rain making. Charitable corporations are formed without assets, nor is there responsibility on the part of their members. Nor can the operators, acting as agents of the nonprofit charitable corporation, be held accountable. The neighbors of the rain-making ranchers and the Nation generally are thus left holding the sack in event of damage. Income-tax liability—I hope there is a representative, Senator, from the Internal Revenue Department here, also, at these hearings—is evaded under the false guise of a nonprofit, "benevolent and charitable purpose." Further, we all know that it takes years of training to make a scientist, but a law like this makes a scientist out of every farm boy with a blow torch and a salt cellar.

Hearings on the above-mentioned bill lasted less than 45 minutes. The president of the State school of mines, and one of the world's outstanding scientists in the field of artificial precipitation, rose to testify as to the dangers inherent in such legislation. The chairman of this committee of the State legislature holding the hearings told him to sit down before he had gotten well started in his remarks.

The entire hearings were called off 10 minutes later. Unless vetoed by the Governor that bill is now the law of the land in New Mexico, and, gentlemen, the president of our school of mines is not here at these hearings, because he is the president of a State school which is subject to this legislature.

It is thus obvious that the legislatures of at least some of our States cannot be expected to be more mindful of national public interest than the local lobbies which control them.

While New Mexico is desperately in need of rain, it is also true that the State is not provided with adequate flood-control facilities, in the event these attempts at rain making prove too successful and abnormal rains result. A 4-foot flood stage on the Rio Grande will drown out the biggest city in the State and four other towns. Yet flood-control protection provided by the Flood Control Act of 1948 is stymied for lack of construction of flood-control facilities.

Now, here is a concrete example of how rain makers may clash with the public interest.

Last summer a highway contract, involving Federal-aid funds, was let for reconstruction on United States Highway No. 87 in northeastern New Mexico. Rain makers had been employed by a group of ranchers to try for additional precipitation in that section of the State. Highway work and rain-making operations were carried on simultaneously, but not hand in hand.

Heavy rains occurred. Whether there was any cause-and-effect relationship between the rain making and the rain has not been established. But the road contractor found his ability to perform under his contract impaired by the heavy rains. Having no sound basis of evaluation himself, he took the rain makers' claims at face value. Accordingly, the State highway department asked the rain makers to coordinate their operations with the road contractor, so that essential road work could be completed. They refused. Heavy rains continued. What work had been done has to be redone. The highway has been a traffic hazard for many months. The financial loss to the State—and the Federal Government—has been estimated at about $50,000. The contractor died. Yet there is now no machinery of evaluation to determine whether the rain makers made the rains and caused the damage and, if so, no basis for satisfaction of their liability or for coordinating their activities with all the vital functions of the body politic, State and National.

The Economic Development Commission sponsored a State-wide meeting on rain making last June, at which Dr. Irving Langmuir, of the General Electric Research Laboratory, scientists of the school of mines, and representatives of the Weather Bureau and various commercial rain-making firms spoke. On the urgent plea by Dr. Langmuir, it was agreed by everyone present that all those who might attempt rain making in New Mexico would submit detailed reports of such activities to the New Mexico School of Mines, and that data so assembled from all sources would be correlated by the school of mines and made available for study by all interested scientific, Government, and military organizations.

A few days later, a company which had been represented at this meeting undertook rain-making operations in northeast New Mexico. We wrote asking that they make reports of these activities available

to the school of mines. We received the following reply from their lawyer:

> Our operations are carried out for private contracting corporations and the data relating specifically to our operations is the property of the client. There are also the problems of insurance-company policies which to a great extent dictate the methods in which data is distributed.

It is interesting to note that this letter was written at the same time the afore-mentioned highway contractor was complaining about the damage to his road construction.

I respectfully wish to impress upon this joint committee of the United States Senate that rain making is still in the earliest phase of research; that research is stopped dead in its tracks unless all factors affecting the problem are available for evaluation by the bona fide scientists working in the field. Only Federal legislation can insure that data on operations attempting to influence the Nation's weather be truthfully and completely reported to central laboratories adequately equipped for such purposes and without such double talk as in the letter I just quoted.

Federal control and regulation, to my mind, are ever more imperative now than at any future time. The present situation is supercharged with danger because even our best-informed and qualified scientists still have much to discover in this field.

S. 222 provides for a Nation-wide research program as intensive but as orderly as now provided by Congress for atomic energy.

From past, present, and future research we all will derive a better understanding of this problem, but, until then, all of us are in varying degrees of darkness. Sound and considered judgment should tell us that we should go slowly. The old maxim that it is better to be safe than sorry fits this picture perfectly. It is too new and too great a field to permit the unqualified or the irresponsible to prey on human credulity for personal gain. Weather control, efficient and safe, I am sure all of us here hope will become a reality in our lifetime. Safeguarding and making possible the steps to bring it to reality is a Federal responsibility.

The assistance which S. 222 will provide to the prompt development of this new field is one of the most constructive and desirable features of the bill. It carries out the policy laid down for the Federal Government by the founders of our Nation—helpful to all States and all citizens equally, and granting to no one group privileges which infringe on the rights of others.

That we talk about the weather, but do nothing about it, is no longer true. We must be sure, however, that we do the right thing in the right way.

Thank you, Mr. Chairman.

Senator ANDERSON. Mr. McKinney, just for the record, you are the publisher of the Santa Fe, N. Mex., newspaper?

Mr. MCKINNEY. I am, sir.

Senator ANDERSON. You have ranch interests in New Mexico?

Mr. MCKINNEY. I do, sir.

Senator ANDERSON. You have some acquaintance with business outside of that, do you not?

You are a director of the Rock Island Railroad?

Mr. MCKINNEY. Yes, sir.

Senator ANDERSON. A director of International Telephone & Telegraph, and so forth?

Mr. MCKINNEY. Yes, sir.

Senator ANDERSON. I just wanted to establish the fact that you are a responsible citizen of our State, concerned about this problem.

Senator SMATHERS. I think he expressed his case very well and very eloquently.

Mr. MCKINNEY. Thank you, sir.

Senator ANDERSON. Is Congressman McKinnon here?

Congressman Phillips is not here either, but he wrote me a note and said that he would like to file a statement, and, without objection, any statement of Congressman McKinnon or Congressman Phillips will be placed in the record at this point.

(Congressman McKinnon's statement is as follows:)

STATEMENT IN SUPPORT OF H. R. 7 AND S. 5 BY CONGRESSMAN CLINTON D. MCKINNON, TWENTY-THIRD DISTRICT OF CALIFORNIA

Mr. Chairman, I appreciate the opportunity of appearing before your committee to present a few brief remarks in support of the sea-water-conversion bill, S. 5.

I am the sponsor of its companion bill in the House, H. R. 7.

Early last year, the Secretary of the Interior advised me that he joined with many in Congress in recognizing the great need for increasing the Nation's fresh-water supply; and because of the acute shortage of water, especially in the West, he believed it imperative that each potential source of additional fresh water be explored exhaustively and developed to the maximum practical extent. The vast quantities of salt water right at our Atlantic and Pacific shores are potentially great national resources, and can be tapped by American scientific methods to supply the rapidly expanding demands of our great metropolitan areas on both Atlantic and Pacific coasts. New York City's recent water shortage certainly lends great support to the crying need for additional fresh-water supplies. Just a few days more of dry weather could have had disastrous effects on this great city's population.

At the same time, the increasing drain on the diminishing water supplies for irrigation of agricultural lands can be checked. More than 2,000,000 acre-feet of water now required for municipal and industrial purposes in the California metropolitan areas can be released to meet irrigation requirements that are growing apace with California's increasing population, and expanding national-defense activities on the Pacific coast.

Water shortages are acute in many areas of the United States. Hundreds of thousands of acres of irrigated land are being kept in production only through serious overpumping of the existing ground water. Pumping for irrigation in some of the most highly productive areas in California, Arizona, and New Mexico during the past few years has been at rates more than double the safe yields as estimated by the United States Geological Survey. The same situation exists to a lesser degree in other Western States.

Between 1940 and 1950, the San Diego, Los Angeles, and San Francisco-Oakland metropolitan areas of California increased in population from approximately 4½ million to 7 million, a gain of approximately 53 percent. Estimates forecast a 1960 population for the three areas of 8¼ million.

The present total annual use of water in California is 14,700,000 acre-feet, of which 2,200,000 acre-feet are for domestic and industrial purposes. Requirements for the estimated 1975 population will total 25,600,000 acre-feet, of which 3,900,000 acre-feet will be for domestic and industrial uses. This would mean complete use of California's water resources and would constitute a ceiling on the State's growth of population, industry, and agriculture. We cannot afford to overlook the possibility of obtaining an urgently needed water supply from other than presently available sources, such as through the distillation of sea water.

Distillation by today's known methods is entirely infeasible for municipal and irrigation use both from the standpoint of cost and production quantities. Developmental research on a large scale is warranted in order to hasten the day when it may be feasible to utilize sea water, through distillation, to supplement existing domestic, industrial, and irrigation water supplies.

In conclusion, I sincerely request your committee's favorable consideration of the bill now before you. This legislation has already received Presidential endorsement to the extent that the President has seen fit to request the Secretary of State, the Secretary of Defense, the Secretary of Agriculture, the Secretary of Commerce, the General Services Administrator, the Chairman of the Federal Power Commission, and the Federal Security Administrator to cooperate with the Secretary of the Interior in every way possible in the necessary research, experimentation, and development of an economic means of producing fresh water as is provided for in the legislation now being considered.

I am sure that the testimony presented to your committee by the various Government agencies and other interested parties will bear out the urgency of this legislation and hereby recommend that the bill be reported favorably.

Senator ANDERSON. Is Dr. Barnes here?

Mr. BARNES. Yes, sir.

Senator ANDERSON. Will you come forward, Doctor. Will you identify yourself, please, for the audience?

STATEMENT OF CARLTON P. BARNES, RESEARCH COORDINATOR, AGRICULTURAL RESEARCH ADMINISTRATION, UNITED STATES DEPARTMENT OF AGRICULTURE

Mr. BARNES. I am C. P. Barnes, research coordinator in Agricultural Research Administration, United States Department of Agriculture.

Mr. Chairman, I have with me Mr. Arthur Brown, who is Chief, Division of Forest Fire Control and Research in the Forest Service.

Senator ANDERSON. Come right up, Mr. Brown.

Mr. BARNES. If you would like, we will have him give you a little statement on the interests of the Forest Service.

Senator ANDERSON. I am sorry Senator Case is not here at this time, because he is very much interested in this phase of it, being particularly anxious to hear any statements made with reference to the Forest Service.

Mr. BARNES. If it is agreeable to you, Mr. Chairman, I will read a summary of the report that our Department has made on these three bills.

Senator ANDERSON. Go right ahead.

Mr. BARNES. Regarding S. 222, we foresee the need for Federal regulation of weather-control activities. Certainly there is need for correlating research and for exercising proper control over independent local efforts to modify the weather. At the same time, we wonder if you might not be able to devise a somewhat simpler and less costly organization to serve this end than the one proposed in the bill. We are not prepared to suggest just what form of organization this might be, but merely wonder whether it might be worth trying to design something less complex.

We express the hope that agricultural interests might have adequate representation in any organization that is established, because of the special importance of weather manipulation to agriculture.

Senator ANDERSON. Doctor, you recognize that there were two ways in which this could have been approached, one by a sort of loose, informal gathering together of reports and additional periods of study, or an attempt to move rather rapidly by the rather strong provisions that are in the bill.

It was a matter on which there was a great deal of argument by the various groups that met regularly to try to write a bill, and I think

probably the deciding factor, as far as I was concerned, at least, was this very information which the Department of the Interior has presented as to the rapid growth of these contracts.

When you have nearly all of one State and two-thirds of another under contract with professional rain makers, costing $200,000 in a single State of which we know, and then if bonuses are paid the probabilities are it can run into $500,000 within that State, then it possibly is not too much to expect that the Government might look at it in a little stronger fashion than if it were something for the future.

Mr. BARNES. I am fully persuaded, after being here, that that is true.

Senator ANDERSON. Thank you, Doctor.

Mr. BARNES. Regarding S. 798, this bill appears to give the Department of Agriculture principal responsibility for research in rain making. Perhaps it wasn't so intended, but we thought it might be so interpreted. We should like to have authority to do research on some of the aspects of weather control, but doubt that we are prepared to take over the major Federal responsibility for research in this field. We should expect to cooperate closely with the Weather Bureau in work of this kind, and we believe we should look to it for primary or, at least, coordinating responsibility in this field.

We should prefer that the authorization be broadened to cover research in cloud dissipation or other means to reduce lightning, hail, windstorm, and flood damage, and that the authority to contract research be specified. We also suggest that the authorization not restrict the Secretary to the use of specific bureaus of the Department. This change would be in line with recommendations of the Hoover Commission that authorities be vested in the heads of agencies.

In our report on the bill, we have suggested amendments to cover these provisions and favor enactment of the bill with these amendments.

There is one other thing that I forgot to put in this digest, and that is: If the committee should see fit to amend the bill so as to provide contracting authority, it might wish to consider some clause by which contractors would be absolved of responsibility in case of claims brought against them for damages.

Regarding S. 5, we believe the discovery of economically feasible means of producing fresh water from saline water might afford large benefits to agriculture in certain areas, and would produce far-reaching benefits to the public in other respects. We also believe that further research, not only in rain making but other aspects of weather control is needed.

We favor, with certain amendments, enactment of S. 798, as a means of providing our Department authority to do research in weather control. If, however, the committees considering weather-control legislation prefer this bill, S. 5, as the vehicle to further authorize weather-control research in the Federal Government, we suggest its amendment to authorize the Department of Agriculture to conduct research in the practical use of the techniques of precipitation induction to provide moisture for crops and pastures, and prevent forest fires, and to discover practical means of cloud dissipation to reduce damage from lightning, hail, windstorm, erosion, and floods.

We believe that the bill also might well provide that the Departments of the Interior and Agriculture cooperate as closely as possible with the Department of Commerce in their conduct of weather-control research, in view of the experience and scientific staff of the Weather Bureau.

Senator ANDERSON. Senate 798 is Senator Case's bill. I see Senator Case is here now, and I do not know whether you have questions to ask, Senator, or not, but the Department feels that this bill might possibly be enacted and give it authority for research in cloud dissipation, methods of reducing lightning and hail. They did not feel that they should have the primary responsibility necessarily for all rain-making activities.

Senator CASE. Mr. Chairman, it really was not so intended when you consider the whole field of research. What I had in mind was that through the Soil Conservation Service and through the Forest Service the Department of Agriculture has a recognized responsibility for fire control and for measures which affect soil and water conservation.

It seemed to me that, with soil districts organized in so many of the counties of many of the States now, the Department of Agriculture has a grass-roots connection with the problem, and it was appropriate that the Department have the direct responsibility there.

In fact, it seems to me that, from the standpoint of getting immediate results or early results, the Soil Conservation Service offered an opportunity of reaching more farmers and ranchers than any other agency. That was why I suggested that.

Mr. BARNES. Yes; that may well be true. You noticed the recommendation that the authority be granted the Secretary without any qualification. That is a policy which we have been following in the Department for quite a while now, trying to get all authorities vested in the Secretary straight so that in the event of reorganization he will not have difficulties.

Senator CASE. I noticed the amendments were suggested in the report which you submitted on the bill.

Mr. BARNES. Oh, yes. That would not, of course, make it impossible to use the Soil Conservation Service if the Secretary so chose to do, and very likely he might.

Senator CASE. I do not think that that amendment is objectionable at all.

Senator ANDERSON. You do like to center research, however, in the Department of Agriculture and the Agricultural Research Administration. The actual field work might be done by some other group.

Mr. BARNES. The Agricultural Research Administration has direct responsibility for a certain part of the research in the Department. It has coordinating responsibility for research in the Forest Service too, and SCS.

Senator ANDERSON. I think, Mr. Brown, we ought to have a statement from the Forest Service, if we could.

Mr. BROWN. Thank you, sir.

Senator ANDERSON. May we have your name, first, for the record, as usual.

STATEMENT OF A. A. BROWN, CHIEF OF THE DIVISION OF FOREST FIRE RESEARCH, UNITED STATES FOREST SERVICE

Mr. BROWN. I am A. A. Brown, Chief of the Division of Forest Fire Research, Forest Service.

The Forest Service has been following with keen interest for several years all the results from new developments that might have useful application in the management of forest and associated range lands. In doing so we have kept in close touch with the experiments carried on both by the agencies engaged in Project Cirrus and by the Weather Bureau in its cloud physics projects. Consequently, proposed legislation in regard to cloud seeding is of much interest to the service.

Authorizations such as contemplated in S. 798 for the Secretary of Agriculture to engage in research in artificial means of modifying local weather would assist the work of the Forest Service. As stated by the Department such research should be on a cooperative basis with the Department of Commerce and others professionally qualified in this field.

The most useful form of such research would be in field testing of techniques to determine the practical value of cloud seeding for various useful purposes. We believe that the more fundamental research in cloud physics should continue to be conducted by the specialists in this field and fully cooperative arrangements would be highly important on this account.

Potential usefulness of cloud seeding in work of the Forest Service concerns the dissipation of clouds as well as the seeding of clouds to induce precipitation. The potential uses that would be most important if proved practical would be alleviation of drought conditions on forest ranges, improved distribution of rainfall during the season to improve forage and forest growth and to reduce fire hazards. Because the headwaters of so many of the important drainage basins of the country are within the national forests, it would be of great significance to water users if it were possible to materially increase the snow pack and water storage on important watersheds.

One specialized interest of importance to the Forest Service is the possibility that cloud seeding techniques may prove valuable in preventing violent local lightning storms at their source in the mountains. Such storms which are termed "dry lightning" often produce little rain but cause a very great number of lightning fires throughout the Northwest and Southwest every year and are extinguished only at a very high fire-fighting cost. The damage they do in a dry year is often disastrous, as shows up in the headlines every year.

In addition to such possibilities there seems to be hope that cloud seeding techniques might be used to advantage in facilitating the control of forest fires under some conditions. Already several claims have been made by cloud seeders that their action stopped a particular fire. We had a number of reports this year on that which we cannot verify.

We should like to see all the possibilities thoroughly explored to determine any public service value that may exist in this field. The two possibilities of usefulness in forest fire work have considerable promise even in the absence of ability to produce large quantities of precipitation. If the number of lightning strikes can be reduced in important forest country this would be an important objective in

itself. When forest fires are burning, even an increase in humidity of the air is often sufficient to slow down the spread and make the fire amenable to control by conventional methods.

Each of these possibilities of employing cloud seeding techniques for public service purposes are in the nature of applied research rather than fundamental research and would consist of putting the results of fundamental research into use.

The Forest Service believes this kind of effort could be very profitable and would supplement rather than duplicate the very fine cloud physics experiments and investigations that are already in progress.

Senator CASE. Mr. Chairman, I think Mr. Brown in his last words there has pointed out the difference between the thing that was talked about in the discussion with the Weather Bureau yesterday and what is sought to be accomplished by S. 798.

The Weather Bureau yesterday was talking about fundamental research or even theoretical research. What I had in mind in proposing S. 798 and in particular in making a specific responsibility about the Department of Agriculture, was for what you called applied research, practically getting into the demonstration field. The Forest Service already has planes, and I am sure Mr. Brown will bear that out.

Mr. BROWN. That is right.

Senator CASE. Which are used in fire control.

Mr. BROWN. They are.

Senator CASE. You have parachute jumpers. I have seen demonstrations of how they operate. With those planes and with men who are accustomed to using them in fire control, if they could add to their techniques the use of seeding of clouds with dry ice, the benefits would be obvious.

Mr. BROWN. I might add there, if I may, that there is perhaps another advantage in that we have some pretty large areas of back country where tests could be run without danger of conflicting interests.

Senator CASE. And you have areas that are difficult to get at when there are forest fires, except by plane.

Mr. BROWN. That is right.

Senator CASE. Absence of roads, rough terrain.

Mr. BROWN. That is true.

Senator CASE. How much money do you use, approximately, each year in fire control?

Mr. BROWN. We use approximately $7 million in suppression funds, and as you may recall, the fire-fighting funds vary with the year.

Senator CASE. According to the demand, the number of fires you have?

Mr. BROWN. According to the demand. Last year was a very high total of approximately $6 million.

Senator CASE. $6 million in addition to the $7 million. The $7 million is your normal suppression money?

Mr. BROWN. Yes.

Senator CASE. $6 million was the demand by reason of fires?

Mr. BROWN. That is right.

Senator CASE. How many acres of national forests are there in the country?

Mr. BROWN. About 181 million. I do not recall the latest figure.

Senator CASE. Have you ever made a dollar estimate of the value of the timber on those lands?

Mr. BROWN. Such estimates have been made. I am sorry I could not quote you a reliable figure.

Senator ANDERSON. You may put in the stumpage value in the transcript.

(The information requested, subsequently submitted, is as follows:)

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
Washington, March 23, 1951.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Subcommittee of Senate Committee on Interior and Insular Affairs, Interstate Commerce, and Agriculture and Forestry, United States Senate.

DEAR SENATOR ANDERSON: Reference is made to the testimony presented for the Forest Service before your joint committee by Mr. A. A. Brown on March 15.

At that time Senator Case requested that information on the present value of the National Forests be inserted in the record. This information is as follows:

An estimate of the present market value of all commercial national forest timber must unavoidably be subject to a number of assumptions. An indication of the value of the commercial timber on the national forests can be obtained as follows: There are 517 billion board feet of commercial national forest timber in the States plus about 83 billion board feet in Alaska, making a total of 600 billion board feet. The average value of timber being cut from the national forests at the current rate of 4.2 billion feet annually is approximately $10 per thousand board feet. Hence, if present value levels prevail, the present commercial stand of national forest timber would ultimately yield $6 billion.

Sincerely yours,

LYLE F. WATTS, *Chief.*
By A. W. GEORGE.

Senator ANDERSON. It is pretty hard to estimate when you have areas that are so inaccessible it is not possible to harvest the timber crop.

Mr. BROWN. There is also the degree of merchantability because of access.

Senator CASE. All the greater reason for insurance and protection against fire.

Mr. BROWN. Originally, of course, you have to fix what price level you are going to assume.

Senator ANDERSON. Stumpage has moved up rather rapidly.

Mr. BROWN. Very rapidly.

Senator CASE. Just one final question, Mr. Brown. Would the Forest Service feel that if S. 798 were enacted that it would be in a position to use the authority and the program therein suggested?

Mr. BROWN. Yes. I would like to add, of course, that there would probably need to be some funds before we could proceed. Our fire research fund is a very tiny one. It is $125,000 for the whole country.

Senator CASE. Would it not be possible for you to use the planes that you now have and the parachute crews for the purpose of some experimental work?

Mr. BROWN. That could be done perhaps. There would be the question, of course, of the degree of diversion of funds that could be made.

Senator ANDERSON. The Army has available right now at the same spot where most of these are stationed the types of planes from which

a great deal of seeding has been done. You could cooperate with the Army and it would probably be more advantageous to you and you could use their planes, could you not?

Mr. BROWN. That is quite possible because higher climbing planes than smoke-jumping planes would be needed.

Senator CASE. I might call attention to the fact that one portion of the bill provides for the use of facilities of other agencies of the Government where that arrangement can be made.

Senator ANDERSON. You have 180 million acres or something of that nature in all the forests of the country?

Mr. BROWN. That is right.

Senator ANDERSON. There is one rain-making organization that is trying to get 200 million acres under its operations.

Mr. CASE. Do you know, Dr. Barnes, how many counties are now organized in soil conservation districts?

Mr. BARNES. I could not give you the number of those right offhand. I can supply it to you, I think.

Senator ANDERSON. You can give the acreage, can you not, also for the record?

Mr. BARNES. I could not tell you the acreage either. It is very large. It is a substantial part of the United States at the present time.

(Mr. Barnes subsequently submitted the following information in reply to the above inquiry:)

Extent of soil-conservation districts, Jan. 1, 1951

Number of counties which are wholly or partly in soil conservation districts (out of a total of 3,069 counties in the United States)	2,540
Percentage of whole land area of the United States that is within soil conservation districts	66.7
Percentage of farm land in the United States which is within soil conservation districts	75
Percentage of all United States farms in soil conservation districts	81.4

Senator CASE. In the organization of the Department of Agriculture, either through Soil Conservation Service districts or through the county extension service, you do have contact with the famers in every county in the country, do you not?

Mr. BARNES. Yes; we have means of reaching virtually any farmer in the country, and do reach most of them in one way or another.

Senator CASE. With technical advice?

Mr. BARNES. With technical advice, with other forms of help.

Senator CASE. And with some field service through the soil conservation districts?

Mr. BARNES. The technical advice is the present thing we offer to the people in the soil conservation districts, technical help in farm planting and installing conservation practices.

Senator CASE. In soil-conservation practice or soil land and water conservation.

Mr. BARNES. Soil, land, and water is the better term.

Senator CASE. You make conservation-benefit payments on the basis of dams built, wells developed, springs developed?

Mr. BARNES. Those are included among the things, I believe, for which payments may be received under the agricultural conservation program.

Senator CASE. I am sure that the chairman of the committee knows that a whole lot better than the rest of us.

Senator ANDERSON. There is a difference between the soil conservation program and the agricultural conservation program.

Mr. BARNES. Yes; there is.

Senator ANDERSON. Between one and the other the point that Senator Case, I think, is trying to make is that, in the various activities of the Department of Agriculture, whether it be Soil Conservation Service or agricultural conservation program, or Forest Service or dealing with the county agricultural agent, you do have contacts with the farmers of this country that could be very useful in this work.

Mr. BARNES. That is certainly true.

Senator ANDERSON. I think it is a very valid point.

Senator CASE. And with the water problem at the grass roots.

Senator ANDERSON. Yes. Thank you.

Is Dr. Howell here now? If not, we will adjourn until tomorrow at 10 o'clock, when Mr. Vannevar Bush will be the first witness in the morning.

(Whereupon, at 12:35 p. m. the hearing was adjourned, to reconvene on Friday, March 16, 1951, at 10 a. m.)

WEATHER CONTROL AND AUGMENTED POTABLE WATER SUPPLY

FRIDAY, MARCH 16, 1951

UNITED STATES SENATE,
SUBCOMMITTEES OF THE COMMITTEES ON
INTERIOR AND INSULAR AFFAIRS,
INTERSTATE AND FOREIGN COMMERCE,
AGRICULTURE AND FORESTRY,
Washington, D. C.

The subcommittees met, pursuant to recess, at 10:10 a. m., in room 224, Senate Office Building, Senator Clinton P. Anderson presiding.

Present: Senators Clinton P. Anderson, Herbert H. Lehman, George A. Smathers, Guy Cordon, and Francis Case.

Also present: Mills Astin, chief clerk to the Committee on Interior and Insular Affairs.

Senator ANDERSON. The committee will come to order.

Will you come up here, Doctor?

Doctor, if you will, identify yourself for the record, please, before you start.

STATEMENT OF WALLACE E. HOWELL, RESEARCH METEOROLOGIST, BLUE HILL METEOROLOGICAL OBSERVATORY, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Mr. HOWELL. My name is Wallace E. Howell. I am research meteorologist at the Blue Hill Meteorological Observatory, Harvard University. I am director of the Mount Washington Observatory, and I have directed the rainfall stimulation experiments for the city of New York. I am appearing before this committee as an individual.

Senator ANDERSON. Thank you, Doctor; we are very glad to have you here.

Mr. HOWELL. Thank you.

Mr. Chairman, the question has been raised, and partly answered in earlier testimony, whether artificial influences can materially influence the weather. On the basis of my own experience, I believe that they can. Furthermore, I believe, from my own experience and from earnest thought and discussion over a period of more than 3 years, that the use of these influences creates certain needs for Federal legislation. It is my thoughts about these needs that I would like to present to this committee and commend to it the task of framing legislation to meet them.

The first need I shall mention is for methodical investigation and research on artificial influences on weather. There are several reasons why I believe that this should be done under Federal sponsorship and

control: The potential value to the Nation of even a small degree of control over weather is enormous; full investigation of the questions both of underlying scientific principle and of practical application will require broad, coordinated effort which no other agency is now prepared to exert; and, finally, and I shall mention again, the experimentation requires some regulation of individual activities and orderly disposition of liabilities on a national scale. As you have yourself pointed out, Mr. Chairman, the legislation should be framed and the investigation planned to take advantage of the efforts already being exerted in these directions and the organizations and facilities in and out of the Government, already available to further them.

The second need I shall mention is for regulation in the public interest of activities for weather modification. The weather runs everywhere through the fabric of our national life, exerting direct, material influence on it at myriad points. Our direct concerns with it are individual, corporate, and governmental—and I believe I place those in the correct order—individuals: housewives, carpenters, farmers, back-yard gardeners, right down to children going out to school or play, putting on rubbers and catching colds: corporations, railroads, airlines——

Senator ANDERSON. Doctor, do you have additional copies of your prepared statement?

Mr. HOWELL. Yes, sir.

Senator ANDERSON. I broke in, because you are a person who has been doing this practical rain-making work, and I think with good results, and I am sure that all of these people here are going to be very much interested in the testimony as the members of the committee are. I want that to be taken into account.

Mr. HOWELL. Let me continue—airlines, shippers of perishables, department stores, circuses, the many manufacturers who use the atmosphere for disposal of wastes; Government: the Departments of Agriculture, Commerce, Interior, and numerous bureaus whose names and claims are more familiar to you than to me—this one claiming jurisdiction of the water that gets behind dams, that one to the water that seeps through the ground, and the other to the water that creeps up a cornstalk. But weather cuts across them all. Weather, gentlemen—windburn, sweat, and chilblains, not just water. But Government is the only agency that can act in behalf of all, and the one that has the duty to do so.

Now let me be more explicit about the public interest. Because the effects of weather on individual activities are so enormously diverse, there are bound to be endless conflicts of interest—between those who wish the weather drier and those who wish it wetter, warmer or cooler.

The city of New York considered that there was a deficit of rainfall in an area where the average mean rainfall was over 50 inches.

The question of competition for available atmospheric sources of moisture may well come up if seeding becomes as widespread as present trends indicate it may. Who but the Government can resolve these conflicts with justice and for the general good?

Then comes the question of damages, of indemnification for people or interests harmed. There is no precedent to which the common law can turn, even in riparian rights, for atmospheric rivers do not flow between fixed banks, and the line cannot be drawn clearly between

fortuitous and humanly caused weather occurrences. Again, new legislation is needed to establish the liability in an orderly way.

To shift the emphasis now to the regulation in the public interest, it appears that safequards are called for not only with regard to the purposes of activities for weather modification but also with regard to the manner in which they are conducted. It seems within the realm of possibility that indiscriminate seeding may lead to local or conceivably even widespread floods, with concommitant havoc.

For the protection of the public, therefore, cloud-seeding activities should be confined, by a licensing procedure, to responsible interests employing professionally qualified personnel. I have already recommended to two State legislative committees, and I would repeat it to this committee, that the professional requirement be qualification for professional membership in the American Meteorological Society, a society associated with the National Research Council. (In this general regard, may I digress a moment to comment on the question that arose yesterday as to separate regulation of seedings by dry ice and by silver iodide. Apart from the very widespread, periodic effects that have been reported by the General Electric group, more or less widespread effects—and by this I mean more than State-wide but less than Nation-wide effects—seldom follow local seeding with either agent, the weather usually being such that it returns quickly, after the seeding, to its previous course; but it appears likely that more or less widespread effects may occur under particularly propitious weather conditions, the seeding then causing the weather to diverge widely from the course it would otherwise have taken. When the weather is so, the spread of the effect is due to the atmospheric reaction, not to the persistence of the seeding agent, and it is immaterial what seeding agent is used. In my opinion, therefore, there is no basis for making a distinction between the seeding agents.)

But to return to my topic—a second need for regulation of cloud-seeding activities arises from the interference that indiscriminate seeding could cause with the highly necessary methodical investigations that should and will be conducted. Since others have made this point, I shall not dwell on it further.

Senator ANDERSON. When you say there should be no difference between seeding agencies, does that mean——

Mr. HOWELL. Between seeding agents.

Senator ANDERSON. Does that mean that you would not draw a distinction between dry ice and silver iodide?

Mr. HOWELL. That is correct; that is for regulatory purposes.

Senator ANDERSON. Yes.

Mr. HOWELL. Finally, regulation appears necessary at the present stage in the development of the science to protect the public from unscrupulous commercial exploitation of the wide possibilities and inviting horizons opened up.

For example, I have already learned of an occasion where my own name has been used without any authorization in the solicitation of commercial rain-making businesses by a practitioner who has no recognized commercial and professional standing.

One more need that I believe that the legislation should meet, and then I shall be through: Weather, of course, is no respecter of political boundaries, county, State, or National. Whatever the nature of the legislation is, it should provide ultimately not only for interstate but also for international cooperation.

Thank you.

Senator ANDERSON. Thank you very much.

Senator CORDON. Mr. Chairman, we are not going to let this witness get off the stand——

Senator ANDERSON. With that little bit; no, indeed.

Senator LEHMAN. I am very sorry I missed your statement, Dr. Howell. I understand that you carried on the work in New York State?

Mr. HOWELL. Yes, sir; I did.

Senator LEHMAN. Was silver iodide or dry ice used in that?

Mr. HOWELL. We used mainly silver iodide. There were a few of the stations that also used dry ice.

Senator LEHMAN. Did you note that the effect of your experiments was felt at long distance from the spot where they were carried on?

Mr. HOWELL. I have not investigated the effect at long range. The effect did show up as far away as the Berkshires.

Senator LEHMAN. They were carried on in the Catskills?

Mr. HOWELL. In the Catskills; yes.

Senator LEHMAN. Thank you.

Senator CORDON. What is the distance between the two?

Mr. HOWELL. Oh, roughly 50 miles.

Senator LEHMAN. I think it is a little more than 50 miles. I do not know what part of the Catskills you carried them on in, but I should think it would be nearer 75 or 100.

Mr. HOWELL. I have a map right here. Shall I check it?

Senator LEHMAN. Well, you probably know it.

Senator SMATHERS. I did not hear the first part of your testimony either. How successful were your experiments in New York?

Senator CORDON. Senator, he really did not get into that. The witness, up to now, has limited himself to recommendations in the controlled field. That is the reason for my observation that we were not going to stop at that point. He is just beginning now with any recital with reference to that.

Senator ANDERSON. He had reviewed the necessity for Federal control.

Senator SMATHERS. I see.

Senator ANDERSON. And in the closing paragraphs indicated that it had to be more than just Federal control to operate among States; it was necessary to operate among nations.

He pointed out that indiscriminate seeding can lead to floods; that there needs to be the establishment of some liability in an orderly way in doing these things, which we have tried to do in this legislation, and suggested that seeding might be limited to responsible parties with professional standing, perhaps membership in the American Meteorological Society, with which a good many of us are in very thorough agreement. Doctor, I want you to understand that.

Senator SMATHERS. Mr. Chairman, you are going to have him tell about what he thinks of this whole system?

Senator ANDERSON. Yes, indeed.

Senator SMATHERS. With respect to weather control, I hope.

Senator ANDERSON. We would be very happy to have him give us any observations he can give us about this entire program.

May I get to something in here?

I just received a letter that is far too long, with the enclosures, to put in the record, but it is from a rancher in Colorado who is quite distressed over this general situation.

I had written him because he had circulated a publication suggesting the best way to bring me under control would be to get down into the political realms in my own State, and defeat me for public office, which was very effective, I am sure; and I wrote him back and told him that that had also been tried before by stockmen, but suggested to him that we ought to discuss these things; and he came back with something that possibly I had overlooked. He said:

> The thing that our associations are afraid of in your bill is because you did not take them into your confidence and let them know what you were doing, and ask their opinion of the provisions that affect them.

That came as quite a blow to me, because I thought I had circulated copies of my bill pretty generally, in its rough draft, and then a secondary draft, and then another draft.

Did you receive any copies of it?

Mr. HOWELL. I received a copy of the final draft.

Senator ANDERSON. In mimeographed form before it was introduced?

Mr. HOWELL. Yes.

Senator ANDERSON. Did you receive a copy of a printed form?

Mr. HOWELL. Yes; I did.

Senator ANDERSON. We thought we had covered everyone who would be interested. We covered Dr. Krick's organization. Dr. Krick came to my office and read and discussed the sections of it, but apparently these people have been persuaded that I was trying to do something stealthily, and I want to say to you, as I have tried to say to others, that ranchers, farmers, any group that wishes to, as far as I am concerned, can have their private rain makers. We are not, or at least I am not, trying to make it impossible for them to have individuals, but I do believe, as you have pointed out, with the possibilities of damage from floods, and so forth, that there ought to be, one, some knowledge of what they are doing, what they are seeding, and where they are seeding and, second, that there ought to be some slight standards raised, at least, that these people ought to have, and certainly a knowledge of meteorology, it would seem to me, would be one of the very first requirements that a man ought to have before he gets into this field.

Frankly, I have felt that Federal legislation would be of great assistance to those rain-making groups that do try to use scientific methods and do try to give the purchasers of their services satisfactory dealings, because, in the first place, it would confer upon the individual who did get regulation some sort of start in the field at least and, perhaps, almost a monopolistic start in the field.

An analogy was used by one of my friends here the other day when he pointed out that in the early days airplanes began carrying people around; Captain Rickenbacker would fly them around from one part of the country to another, and along came the Civil Aeronautics Authority and put him under control; yes; but made it possible for him to build Eastern Air Lines, because he had an established route, and a Government license to work with. The same thing with the flyers who flew across the western parts of our country.

There is not much that now resembles the early barnstorming flights that came across there. Now there is some degree of Federal regulation, but there is also a well-established industry.

I want to make plain to you, as I hope it will be made plain to others, that the last purpose I have is to prevent a group from having a private rain maker if they wish to come to their area and work. My feeling is that, if he has the proper scientific approach, he will not mind having pelple know that he is there, and what he is doing, and it is on that theory with which I am working.

With that preliminary, we will be very happy, I am sure, all of us, to have you discuss your work in New York State just as frankly as you feel like doing it.

Mr. HOWELL. Well, I would agree with you that the purposes are certainly valid, and it would seem to me that the stockmen, as much as anybody else and, perhaps, more than most, would benefit from orderly development of this science, and orderly regulation, at least the stockmen, as a group, even if some individuals felt that they had grievances.

In reference to the New York work, we did, of course, make an effort to augment the water supply of the city by cloud seeding in the region of the Catskills. This was carried on on 36 occasions when the weather was just auspicious over a period of 31 weeks from April to December of 1950.

During these 31 weeks that were available for seeding, the precipitation in the Catskill region exceeded the amount that would have been expected on the basis of comparison with precipitation amounts in surrounding areas by about 14 percent.

On several occasions, on several separate occasions, when cloud seeding was done, there was relatively greater rainfall in areas where the seeding might reasonably be expected to be effective. It appears likely to me from the evidence that the cloud seeding did augment the precipitation on several occasions and that it did cause the rainfall over the Catskills during this period to be about 14 percent more than it would otherwise have been, yielding something of the order of 15 billion gallons of additional water to the reservoir system.

Senator ANDERSON. Would you mind telling us, if you have the information, what was the situation in the New York reservoirs, Croton Reservoir and others, and what it has become since? I realize that you are not trying to take full credit for all the improvement in the reservoir, but just in order that we may have that picture in front of us.

Mr. HOWELL. The reservoirs were badly depleted in the autumn of 1949 by a particularly hot summer and particularly heavy draft on the system.

Storage fell to a low of approximately 30 percent of capacity in late November and early December 1949. Later on it began its usual winter increase and, at the time the seeding experiments were begun, it stood at about 40 percent of capacity. The rainfall held up, and the reservoirs became completely full in November, in late November and early December this year—no, make that December of this year.

Senator ANDERSON. In other words, the threatened water shortage in the city of New York has been averted?

Mr. HOWELL. Has been averted.

Senator ANDERSON. They may have to be careful.

Mr. HOWELL. But not, I must stress, by these 15 billion gallons, because that is only 2 weeks' supply for the city. The conservation campaign was responsible for a much greater saving of water than was contributed by any possibility here.

Senator ANDERSON. I think that is what commends your testimony in your general appearance here to most of us, Doctor. You do not try to take credit for all of it, and you do recognize that other things can happen, and we appreciate the fact that you do come here and just try to give us a scientific appraisal, if it is possible, to augment it, and certain other things can also happen.

Senator CORDON. Fifteen billion gallons represent how many days' use?

Mr. HOWELL. About 2 weeks' use.

Senator LEHMAN. Does your statement contain a definite figure of 15 billion gallons which you claim to have brought about?

Mr. HOWELL. I have said about 15 billion gallons, and this is a tentative result, and there must be further work done on it. However, I do not think that any further perfection of the comparison will change the nature of these conclusions.

Senator LEHMAN. What I am getting at is this: I was in favor of carrying on those experiments, but what proof do you have that this 15-billion-gallon increase is directly attributable to the experiments that were carried on, the work that was carried on?

Mr. HOWELL. The nature of my proof is in two parts: One, by direct comparison station by station covering about 120 stations in the immediate surroundings of the watershed of the amount of rainfall during this 31-week period that was available for experimentation, with the preceding 13-year period from 1937 to 1949, that representing the longest period that there was a very good coverage; many of the water stations were established in 1937 by the board of water supply.

Senator LEHMAN. Well, do I understand that the 15 billion gallons which you claim were brought about through your experimentation, was that the limit of what you could have done or did you arbitrarily limit your efforts to a certain locality or a certain period?

Mr. HOWELL. I arbitrarily limited my efforts to a certain locality, the Catskills, because I felt that that, more than the Croton or the Long Island watersheds, was favorable to this effort. I was limited in time by the duration of the contract and by practical considerations, and also by interdiction from time to time of the seeding through reasons beyond the scope of the rain-making project itself.

Senator LEHMAN. What I am trying to establish is this: To what extent this could be—assuming now that perhaps we should outline our activity to know what it is, to what extent this could be used as a dependable source of rain making. What I have in mind is this: I believe that the capacity of the various reservoirs is somewhat over 200 billion gallons of water. The consumption, before conservation was put into effect, was about a billion and a half—a billion, three hundred fifty million gallons, a day. Through conservation that was brought down to somewhat under a billion gallons a day.

Mr. HOWELL. That is right.

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Senator LEHMAN. Now, 15 billions is about a 10-day or 2-week supply, as you have stated, and it represents about 6 or 7 percent of the capacity of the reservoirs.

I was wondering whether that could have been increased from 15 to 25 billions or 30 or 40 billions, or whether you exhausted the full capacity of your rain-making facilities?

Mr. HOWELL. I would say that the full capacity was not exhausted, but it represents reasonably well what could be done with the silver iodide smoke from the ground alone, without full airborne operation.

Senator ANDERSON. That is very important.

Mr. HOWELL. During, of course, this particular period. Now, the natural variability of the weather is such that another period might show quite different results. For that reason I do not believe that this very tentative 14-percent figure could be relied on as an estimate of future safe yield. However, this 15 billion gallons is based on two watersheds presently in operation, Schoharie and Esopus watersheds, whereas the new watersheds, Rondout, Nevrsink, East Branch of the Delaware would nearly double the area available and, therefore, nearly double the catch from the rain making.

Senator LEHMAN. You said that the effect was felt as far as the Berkshires. Was it felt south of your operations down toward the Pennsylvania line, too?

Mr. HOWELL. Not that I could determine.

Senator SMATHERS. Mr. Chairman, may I just ask this question?

Senator ANDERSON. Yes, Senator Smathers.

Senator SMATHERS. In pursuance of Senator Lehman's remarks just a minute ago, it was not clear to me whether or not you stated that if you used airplanes and silver iodide from the air, and in greater quantity, that you actually could or could not increase the amount of rainfall.

Mr. HOWELL. I think that the yield could be further increased by that means, yes.

Senator SMATHERS. In other words, you could have raised your 14 percent, you felt or you feel, considerably, had you used a larger quantity and a larger operation?

Mr. HOWELL. I hesitate to say how much.

Senator SMATHERS. Do you see in the immediate future any chance for improvement in this method of rain making?

Mr. HOWELL. I think the problem stands now as one of evaluation rather than improvement. We do not know enough about it to know just what results to expect. Yes, when we know more about it, I have no doubt that improvement would result.

Senator SMATHERS. Are you yourself continuing your experimentation designed, of course, to bring about an improvement in this rain making?

Mr. HOWELL. I am certainly continuing my interest and my studies; I am not at the moment conducting any experimentation.

Senator ANDERSON. But, as an individual who did some work in this field, would you be alarmed by the passage of a Federal bill requiring registration and knowledge on the part of some Federal agency of what you were doing?

Mr. HOWELL. Not at all.

Senator SMATHERS. May I say here that I did not mean by my questions to infer that this legislation is not fine. Frankly, I am a

neophyte at this business of rain making. Down in Florida we have plenty of rain [laughter] so we have not had to worry about it yet, but the day may come. Frankly, I never have seen it work, and you have seen it, and you gentlemen from the West have seen it, and so it is new to me. I ask rather naive questions about it because it is a fascinating subject which I have never seen applied.

Senator ANDERSON. My observation, Senator, had nothing to do with what you said at all. I was just thinking of the opportunity before he got off the stand of asking a person who has been doing this work, and I think has been doing it successfully, whether he would be alarmed in any way by the passage of regulatory legislation that made it necessary for him to register, might even require a licensing in his work, as he went along.

I conceive that that type of legislation is all for the protection of men like Dr. Howell who try to do this in a scientific fashion, and who believe that it is possible greatly to improve our science, as we evaluate what they are now doing.

Senator SMATHERS. Such legislation would in no way lessen your desire for further experimentation or in any way impede your experimentation?

Mr. HOWELL. That is correct.

Senator CASE. Mr. Chairman, I have two questions I would like to ask.

Senator ANDERSON. Senator Case.

Senator CASE. One is, Dr. Howell, by further experimentation and study, you mean the possibility of conducting sufficient experiments under varying conditions so that you can measure the effect of trying rain making under different atmospheric conditions, different wind conditions.

Mr. HOWELL. That is right.

Senator CASE. And for that reason it is important to pursue the subject so that we know more definitely what we are doing.

Mr. HOWELL. Yes. I think that further investigation broadly and methodically is an essential.

Senator CASE. The second question is, Would it be violating your professional work if we were to ask you for a table which would show the stations that you had compared so as to determine the relative rainfall in the area you sought to treat or affect, with the outlying areas?

Mr. HOWELL. No; that information is all on the public record, and it is open to all. In fact, the rainfall figures are published monthly by the Weather Bureau, and I have used all available records from the Weather Bureau.

Senator ANDERSON. Doctor, could you submit to us a table of that nature which we could examine in the committee, and if Senator Case and others think it would help the hearings, that we might add to the hearings?

Mr. HOWELL. I think I could give you a copy of that by Monday. Would that be sufficient?

(The four figures supplied by Dr. Howell appear in the appendixes.)

Senator ANDERSON. That is perfectly all right.

Senator CORDON. Would that, Doctor, be the data which you yourself used in your evaluation?

Mr. HOWELL. Well, what has been requested so far was information as to the stations used.

Senator CORDON. What I am interested in are the data you used.

Senator CASE. I thought that if we could have a table that would show the stations and then, perhaps, a map in which the area could be outlined with the stations located on there, that it would give some idea of the relative effect.

Mr. HOWELL. Well, I started to describe to Senator Lehman the method I had used in arriving at this figure of 14 percent. Perhaps if I continue that a moment this will become clearer.

As I say, I compared the rainfall during the period of experimentation with the average over the 13 years that the detailed records were available, and on this basis I mapped the percentage of the expected rainfall that had occurred at each station throughout the region.

Now, the chart showing the result of this is, as you might expect, a rather complex one, and shows many local details. Here it is.

This chart is on the scale of 1 and 1,000,000. The city of New York is approximately here. This is the Hudson Valley; Albany is here, Binghamton here, the Catskill region here.

Now, there are so many confusing details on the station-by-station chart that I took from this map the values at each 10-mile interval in both directions, and smoothed these 10-mile values, taking the mean of the four-corner values in each 10-mile square to obtain this map. This shows the outline of the watersheds, and it shows the smooth values over this area from Pennsylvania, the corner of Pennsylvania in here, and the Massachusetts line approximately the edge of the sheet.

You see a broad area here where the lines skirt around this Catskill region, and a second area where they loop up around this part of the Berkshires.

This I superimposed on the records so far available from the Weather Bureau's National Climatological Summary which shows the departure of precipitation from normal for the months of this experiment, omitting the month of November which has not yet been published.

That general pattern showed a region of near or above normal precipitation extending out here in the Ohio Valley, a region of subnormal precipitation in New England and northern New York State, and a general trend in this direction of the lines in between. So that these two loops definitely counteract that general trend.

By carrying lines across these to conform with the general trend, I arrived at a preliminary estimate of what might have occurred if seeding had not been done.

Now, I am aware that that is an estimate, and any further conclusion based on it must be tentative. The conclusion that I arrived at was then made by comparing these individual figures with those tentative estimates, and multiplying them by the percentage yield of the reservoir system, as tabulated by the New York Department of Water Supply.

Senator CASE. Was this done before your experiments?

Mr. HOWELL. No; this was done all after the experiments, on the basis of the rainfall data accumulated during——

Senator CASE. I think that is very interesting.

Mr. HOWELL. This I shall make available to the committee.

Senator CASE. I think that would be helpful.

Senator CORDON. Mr. Chairman, I have a number of questions to ask, although I am not in a hurry about it.

Senator ANDERSON. Go ahead, Senator Cordon.

Senator CORDON. Do I understand, Doctor, that the data which you compiled on your several tables represent an average over a 13-year period?

Mr. HOWELL. I have computed the average rainfall at each station, yes, for which the record was available for that period.

Senator CORDON. Do you feel that you could get any satisfactory or reliable conclusion when you compare an average of 13 years against precipitation in 1, having in mind that the average must have overages as well underages?

Mr. HOWELL. Fifteen years are generally considered in climatological practice as an adequate basis for evaluation of the climate.

Senator CORDON. Is it satisfactory as a basis for determining results in a change in climate in 1 year, that is the point I am getting at?

Mr. HOWELL. No; I would not say that it is entirely satisfactory, but it is the best we had to go on, Senator.

Senator CORDON. I am wondering if it is. Could I, if you will pardon me, express any contrary opinion here. Being less than a layman in discussing this matter with the next person—the only head I have is this one, and I will have to use it—it would appear to me that if you could take your year, the year that you worked, and compare that individually with each of the years, making up the total, you might have more reliable data than you would if you took an average over the total. In other words, might it not well be that in the first, or second or third, fourth or fifth of the 13-year period, the variation in this area might well have approximately or even—I do not mean the variation, I mean the precipitation in these several years might each have more nearly approximated the results that you obtained by your seeding operations, perhaps even exceeded them?

Mr. HOWELL. That is true, they may have. In the interests of completeness, the kind of study that you outline certainly should be made.

However, I do think that we have done the best that could have been done with the particular restrictions of time, and so forth, under which we worked. There is plenty of room for further study.

Senator CORDON. Do you contemplate that additional study?

Mr. HOWELL. The Weather Bureau is continuing this study. My contract, of course, with the city is terminated, but the Weather Bureau is continuing it. It has gone so far at a rather halting pace, and their part of the study has not reached the point where any conclusion can be drawn.

It is because of that halting pace that I went ahead and did this admittedly rather sketchy study to find out for my own satisfaction, as well as the city's, what the general order of results had been.

Senator CORDON. Would you recommend that a year-by-year comparison and study by some agency be conducted?

Mr. HOWELL. Yes; certainly.

Senator CORDON. With respect to this particular experiment or operation?

Mr. HOWELL. I very much hope that this particular one can be extended.

Senator LEHMAN. Senator, may I ask a question?

Senator CORDON. May I just submit a couple of more questions?

Senator LEHMAN. Surely.

Senator CORDON. Would the Weather Bureau be, in your opinion, the appropriate agency as of this time to go forward with such a comparison?

Mr. HOWELL. I hate to be pinned down on that, sir.

Senator CORDON. I hope you will permit yourself to express opinions, Doctor, because it is very important to this committee to have your views in this particular field because of your association with the Weather Bureau and its officials.

Senator ANDERSON. It is pretty hard for him though. He has to work with the Weather Bureau right along, and if he should say he did not think the Weather Bureau was the proper agency, that door would be closed to him for quite a while.

Senator LEHMAN. May I just ask this? I do not see why you have to bring the Weather Bureau in this at all. It seems to me that Dr. Howell might be able to give us those facts. If he has reached an average over 13 years he must have the record of each year.

Mr. HOWELL. That is right.

Senator LEHMAN. And it would seem very easy to prepare a table showing the rate for each one of the 13 years, as suggested by Senator Cordon, in comparison to the rainfall in the 1949–50 period.

Senator CORDON. I understood the doctor to say that his primary interest, namely the contract with the State of New York or the city of New York had expired.

Mr. HOWELL. Let us call that, Senator, my primary facility, not my primary interest. My interest continues.

Senator CORDON. I am thinking more, Doctor, with respect to the available time you have. You are in charge of the observatory and divers other matters of that kind which have a primary claim on your time——

Mr. HOWELL. That is right.

Senator CORDON (continuing). Then you may find it difficult to carry this study through within some foreseeable time in the future, when it would be of the most value to this committee.

Mr. HOWELL. That is quite true.

Senator CORDON. And that is the reason I asked whether you felt that the Weather Bureau is the most logical agency now in existence to go ahead and do the job.

Mr. HOWELL. It is certainly the only Government agency in existence at the present time that is equipped to do the job.

Senator CORDON. Well, is it equipped to do the job?

Mr. HOWELL. I say Government agency; yes, it is.

Senator CORDON. Did the Weather Bureau collaborate with you, beyond furnishing the data which you used in your study?

Mr. HOWELL. At the time that the program began in New York the Weather Bureau offered its full cooperation and I am glad to put on the record that the cooperation, both of the Bureau as a whole and of all the individuals with whom I have dealt in it, has been of the very highest order. Does that answer the question?

Senator CORDON. Well, it helps. I have not a complete answer. You can readily understand that that would have been the correct answer to my other question.

I feel, Mr. Chairman, that this committee is entitled to have as fully as possible the data upon which conclusions have been drawn. I think that the conclusions themselves, of course, are valuable and they carry a certain verity because they come from trained minds. But sometimes even untrained minds in meteorology might raise a question as to where there might have been an oversight or where there could have been more information made available than was made available. I think, perhaps, this questioning has indicated something of what I mean

Mr. HOWELL. Now, Senator, at this point I mentioned that there were two types of study, of evaluation that had been made. Maybe this is the time to describe the second one

Taking representative stations that embraced the whole range of mean annual rainfall through the region, we broke down the 13-year record into individual storm rainfall quantities, and arranged those in descending order of magnitude. This provided a means of expressing the distribution of rainfall amount that typically occurred.

Senator CORDON. But still for the average period.

Mr. HOWELL. Still for the average period.

We found that these six records fell in such a regular pattern that we felt considerable confidence in interpolating between them. ow, of course, if the study had been more extensive we should have made these individual records for every available station and not try to reach any interpolative conclusions at all.

As it was, nevertheless, the results looked as if they would not have been changed by much further refinement of the method. This method made it possible to assign to each storm rainfall quantity at each station a value representing its rank standing in the rank list established on that 13-year record.

Senator CORDON. I think I follow you.

Mr. HOWELL. And say that this storm was equal to the one hundred and seventh, say, or some other numbered storm of the 13-year record at that station.

Now, each ordinal rank has an equal opportunity of recurrence, so that this linearized that distribution.

Also since each station was compared with its own previous record, it eliminated the average effect of station exposure relative to the mountains or relative to a tree over the rain gage or any other accidental influence.

For the 12 storms during the seeding period, the 12 seeded storms during that period that gave the heaviest rainfall in the watershed, I made individual maps showing the rank standing of that storm, station by station.

Now, I am going to ask to withhold those maps because of the fact that litigation is pending before the city, but the pattern of them is such that it does show high rainfall in most of these occasions, in regions where it might reasonably be attributed to the seeding, and these patterns though of small scale are sufficient in intensity, you might say, so that I feel considerable confidence that they would not be materially changed in character by a change of the method of analysis.

Senator CORDON. May I suggest for a moment that you leave your field and get into mine? You spoke of a pending lawsuit. I would suggest that so far as they are concerned it might be well if you took that year by year instead of average.

Senator SMATHERS. May I ask one other question? Excuse me, Senator, you go right ahead.

Senator CORDON. Do you contemplate, Doctor, setting up data along the line of that which you have made on a basis of 13-year average on a year-by-year basis?

Mr. HOWELL. I am not sure that I would say quite that. I certainly intend to study in detail comparable individual weather situations from the past that might be considered analogous to the situations that we had during the period of seeding.

Senator CORDON. Well, I hope that when that is furnished, and when you are at liberty to go further, that this committee might hear from you.

Now, the next question that I want to ask you is a little bit apart from that, but we might just as well get it over with because there are others who want to ask you questions. We had testimony at the opening of these hearings from representatives of the Weather Bureau that indicated some doubt on the part of the witness as to the adequacy of proof of results at the present time. I just want to read one paragraph out of that statement, and I quote it:

> Even the most enthusiastic proponents of the present feasibility of rain making on a practical scale claim no more than to be able to extract moisture from the air locally under conditions predisposing to the natural occurrence of rain or snow. Since these experimenters or operators only seek results under marginal conditions or try to increase precipitation after it has started, the proof or disproof of their claims to success becomes doubly difficult and often impossible.

Would you comment on that statement?

Mr. HOWELL. First, the question arises with respect to marginal weather situations. How wide is the margin and how much can it be influenced? A marginal weather situation occurs every time that rainfall begins because that is the definition of a margin.

If each of those margins can be treated and made to yield considerable quantities of rain, then I see no restriction that such a qualification puts on the ultimate usefulness of rain making.

Senator CORDON. Well, of course; but have you not assumed the fact that we have to prove which is the operation which did make the increase? In other words, that there was more rain that fell as a result of an operation than might have fallen had it not taken place?

Mr. HOWELL. That is true. The problem of setting up a yardstick to measure what would have happened if seeding had not been done is a very complex one and one that is full of statistical pitfalls.

Senator CORDON. That brings my next question up: It would appear to me perfectly clear from not only your testimony but essentially all the testimony that we have heard here that the meteorological information in the hands of the Weather Bureau and the facilities of the Weather Bureau to continue its studies is an essential part of any program in this field. Do you agree with that?

Mr. HOWELL. I think that is safe to say, with the qualification that I do feel that other agencies outside of the Government also have very material contributions to make.

Senator CORDON. Well, I would not question that for a moment. But I am just thinking in terms of the knowledge that has been gained by this agency over a great many years in its efforts to predict weather in the future. The experience records that it must necessarily have, indicating the extent of its success and the extent of its failures, and what I would assume to be very intensive study in an attempt to determine the cause of the failures or reasons for the success, that would appear to me to be knowledge absolutely essential to an understanding of what we are trying to do.

Mr. HOWELL. It would certainly take anyone else a long time to accumulate that background; yes.

Senator CORDON. So that in any set-up that might be evolved by law in this field there would definitely be a place for the knowledge and experience of the Weather Bureau in this field.

Mr. HOWELL. Let us say of the Weather Bureau personnel. That is, after all, where the Weather Bureau's experience resides.

Senator CORDON. Well, a great deal of it has been committed to paper, has it not?

Mr. HOWELL. Yes. Still what constitutes the Bureau? Personnel? Paper records?

Senator CORDON. Well, you might not be able to read a person, but you could read a paper. [Laughter.]

Senator ANDERSON. Let me remind the committee that we have been an hour with Dr. Howell, and we have four other witnesses.

Senator CORDON. Just one more question, and I will step aside. We had testimony here to the effect that silver iodide exposed to sunlight lost its efficacy as a rain-making agent in some half hour or something of that sort. What can you tell us about that?

Mr. HOWELL. I have no personal first-hand knowledge of that question. I have heard it reported also from at least two separate investigators.

Senator CORDON. Would you name them?

Mr. HOWELL. One of them was Dr. Vonnegut of the General Electric Co. and the other is Dr. Inn of the Geophysical Research Directorate.

Senator CORDON. Have there been any experiments in that field at Harvard, to your knowledge?

Mr. HOWELL. Not to my knowledge. Dr. Vonnegut was the source of my information that a study had been made. I did not mean to imply that he had made the study.

Senator CORDON. He was testifying here the other day and he testified, I think it is important, in this bulletin put out, or rather an item put out by the National Weather Improvement Association, which is connected with a group of agencies, and addressed to the Country Gentleman, protesting in an article they had—which said that:

> Inasmuch as silver iodide vaporizes and becomes ineffective within an hour or so after the sun comes out it is hard to see just how cloud seeding could affect the weather 2,000 miles away.

Mr. HOWELL. I do not feel myself that the question has been resolved completely; it possesses questions, but does not tell the answers.

Senator ANDERSON. Is Dr. Vonnegut here this morning?

Mr. V. J. SCHAEFER. No; he is not.

Senator ANDERSON. Dr. Schaefer, will you see to it that Dr. Vonnegut supplies us with information on that question? I understand there is a special article coming out in a magazine this month.

Mr. SCHAEFER. That is correct.

Senator ANDERSON. In what is it?

Mr. SCHAEFER. It is in the bulletin of the American Meteorological Society, I believe, this month, February bulletin.

Senator ANDERSON. Does it agree that silver iodide loses it effectiveness in a few minutes?

Mr. SCHAFER. It shows that, so far as our studies are concerned, it loses something in the order of a decrease by a factor of 10, tenfold per hour. In other words, if you put out 10 to the sixteenth power, 1 hour later there will be 10 to the fifteenth; and we also point out that we also know of other things which seem to reactivate the deactivated particles, and those things occur in the natural atmosphere. So it is one of those questions that needs much more work done on it.

(The article follows:)

EFFECT OF SUNLIGHT ON THE ACTION OF SILVER-IODIDE PARTICLES AS SUBLIMATION NUCLEI

(S. E. Reynolds and William Hume II, New Mexico School of Mines, Socorro, N. Mex.;[1] Bernard Vonnegut and Vincent J. Schaefer, General Electric Research Laboratories, Schenectady, N. Y.[2])

Silver-iodide particles as usually dispensed in cloud-seeding operations[3] range in effective size from 0.01 of a micron to 1 micron. The nature of silver iodide is such as to suggest the possibility that it might be "reduced" by ultraviolet and near ultraviolet radiation from the sun. The reported extensive employment of this material in numerous commercial attempts at artificial nucleation evidenced the necessity for determining its rate of decay under expected conditions of radiation in the free atmosphere.

A cylindrical steel tank, open at the top end, having a capacity of approximately 46 m.^{3} was set up at Socorro, N. Mex. The tank was provided with two airtight covers, one made of opaque linoleum and the other of thin cellophane. Silver-iodide particles were introduced into the covered tank from a burner operated in the usual manner, and, after mixing the air with an electric fan, the effectiveness of the airborne silver-iodide particles as ice-forming nuclei was tested at periodic intervals in a laboratory cold box.

When the tank was covered with the opaque cover, it was found that the number of active nuclei decreased about one order of magnitude in 24 hours. When covered with thin cellophane and exposed to bright noon-day sunshine in July, the number of effective nuclei was found to decrease about two orders of magnitude per hour—this second value being corrected for the geometry of the tank to give approximately the free air action of radiation. The loss of nucleating activity under dark conditions results from the deposition of nuclei on the walls of the vessel and, to a lesser extent, to recombination. The loss of activity in bright sunlight has been found to result primarily from the short wavelength radiation. Although spectral energy distribution was not measured during the course of the experiment, it was noted that the decay rate under conditions of radiation by sunlight showed great variation with very light cloud cover and with the time of day.

Experiments similar to those made in Socorro were made in the General Electric Co. research laboratory in Schenectady. Because of the far greater prevalence there of a cloud or smoke cover, these experiments were made by introducing the silver-iodide smoke into a rubber balloon a little over a meter in diameter and having at its center an S4 GE ultraviolet lamp. Periodic examination of smoke placed in this balloon revealed that the ultraviolet lamp caused a rate of decrease in the seeding activity of the silver-iodide smoke of the same order of magnitude as that found in the Socorro experiments.

[1] Work done under U. S. Army Signal Corps sponsorship.
[2] Work done under Project Cirrus.
[3] Bernard Vonnegut, Experiments With Silver Iodide Smoke in the Natural Atmosphere, Bulletin of the American Meteorological Society, vol. 31, No. 5, May 1950.

These experiments which show the deleterious effects of sunlight on silver-iodide nuclei suggest that far greater quantities of silver-iodide particles will be required for seeding operations under conditions of bright sunlight than at night or under conditions of cloud cover.

The experiments carried out thus far at the General Electric Laboratories have shown considerable variability in the rate of decay of the activity of the smoke depending on the particle size and technique of smoke generation. It is possible that further experimentation will yield techniques for inhibiting the photochemical deterioration of silver-iodide nuclei.

Senator SMATHERS. May I ask a hypothetical question of the doctor? I assume it is true that clouds in rainfall, of course, affect the land temperature. Do you think it might be possible in the years to come, through this method of rainmaking and the improvement of it, that you would be able to change the land temperatures?

Mr. HOWELL. To say that they could be changed appreciably would be rather far-fetched, I believe. There might be very slight changes in detail that would be almost impossible to detect.

Senator SMATHERS. Could you change it in degrees is what I am talking about. In other words, if 32°, we will say, is ordinary freezing and citrus growers of Florida were worried about a freeze, and they needed 1° or 2° changes, would it be possible, by seeding clouds, to bring about a change of 1° or 2° and thereby avoid a freeze?

Mr. HOWELL. I do not think it is likely myself, but the subject is so tenuous I might easily be wrong.

Senator SMATHERS. That is all I have.

Senator CASE. Mr. Chairman, I think Dr. Howell's general position was summed up in a sentence in a letter which he wrote to Charles Gardner, who is sitting here, who is now a member of my staff, but at the time was not a member, nor did he know he would be. He said at that time:

My own opinion is that a clear view of the outcome is not yet possible. For my own part, I intend to avoid placing myself in a controversial position with regard to the possibility in the field, but to keep myself fully informed.

In other words, his position is that of taking an exploratory attitude and coming to modifications of conclusions as new data develop. Is that correct?

Mr. HOWELL. That is correct.

Senator SMATHERS. My only purpose in asking that question, of course, is that that would be tremendously important to all fresh-vegetable growers and citrus growers. You need assistance, financial assistance, and it might be that several States would want to contribute to a general or joint project of experimentation on this particular matter.

Mr. HOWELL. I would not want to discourage experimentation, particularly in view of the large economic importance that might be attached to it. But I think that a successful outcome is dubious, to say the least.

Senator SMATHERS. No hope for the citizens of Washington, D. C., then, for the weather to come.

Senator ANDERSON. Are there other questions?

Senator CORDON. Mr. Chairman, I would like to ask one other question. I do not want to delay this too much.

Senator ANDERSON. Proceed, go right ahead.

Senator CORDON. Doctor, would you care to express your views as to whether, from the information now available, it would be possible to

look forward with some hope to weather control that might to some extent be beneficial in inducing rainfall in drought periods, as distinguished from minor seeded areas?

Mr. HOWELL. I think that rain stimulation in drought periods will be about as effective percentagewise as it is at other times and perhaps slightly more effective, because of the fact that the drier the climate becomes the more are the marginal situations ruled out, and only the situations most propitious to rainfall come to the fore. But, as a general rule, I would say that we can guess the effectiveness will be percentagewise the same in drought as in periods of more ample rainfall.

Senator CORDON. One other question: What is your view as to whether or not with the silver iodide you may overseed, and thus reduce rainfall, as well as properly seed and induce rainfall?

Mr. HOWELL. I do not know of any case where a result on a broad scale of overseeding has been shown. It looks to me reasonable that such an eventuality might come about.

Senator CORDON. Are you familiar with the work done in Costa Rica or Honduras, or somewhere in that area, in that field?

Mr. HOWELL. Slightly, yes. I have read the report published by Dr. Langmuir, and also a mimeographed paper, perhaps, going into some more detail.

Senator CORDON. And, when you express your view of lack of adequate information there, you have those experiments in mind as well as others?

Mr. HOWELL. That is right, but that was on a very, very local scale.

Senator CORDON. I have no other questions.

Senator ANDERSON. Thank you very much, Dr. Howell.

Our next witness is Dr. Bush.

I do not suppose we ought to say that you should identify yourself. I suppose the committee, if it does not know Dr. Vannevar Bush by now, we are in a pitiful state; but, if you care to do so, you may.

STATEMENT OF VANNEVAR BUSH, PRESIDENT, CARNEGIE INSTITUTION OF WASHINGTON

Dr. BUSH. I am Vannevar Bush, and president of the Carnegie Institution of Washington.

I have no prepared statement, Mr. Chairman, because I was not sure what you hoped I could contribute to this discussion.

I am not a meteorologist, of course. Perhaps you would like to have me contribute more from the standpoint of how this present state of the affair impresses one who is in the scientific field but not a meteorologist?

Senator ANDERSON. That is correct.

Dr. BUSH. It seems to me that this is a very early art, in its formative stages. My knowledge of it is simply that of reading the literature.

I have looked at some of the confidential reports that are contained in the Air Force study, but it comes primarily from that.

I have become convinced that it is possible under proper circumstances to make rain. I know that there are many who are not convinced as yet. I am convinced myself that it is possible, and I am also convinced that this art is in the state where a great deal more

careful experimentation is necessary before it can be entirely understood. Certainly it is in the state where there is plenty of room at the present time for controversy.

I hope that out of these hearings and out of the action of you gentlemen we are going to have a situation in which that experimentation can be carried forward in a thoroughly satisfying manner, in a way where we can have plenty of experimentation by various groups under conditions where variables can be properly separated, and the whole thing can be studied thoroughly, and the records made carefully. If that is done, then in a few years I think we will know a great deal more about this subject than we do today.

But, as it stands today, we are on the threshold of an exceedingly important matter, for man has begun for the first time to affect the weather in which he lives, and no man can tell where such a move will finally end.

We have today one or two methods; we have made local rain. Who knows, before a decade has passed, we may be affecting the environment in which we live to a very extraordinary manner. So, I think, the matter should be approached, first, from the standpoint that it may become of extreme importance and, second, that today the obvious thing to do is to provide so that there can be plenty of systematic, well-regulated experimentation, all of which will be available to the public and to meteorologists for study and comparison.

I think that is all I have on my mind, sir, except what you may ask me.

Senator ANDERSON. Do you think it is a proper field for Federal interest?

Dr. BUSH. It seems to me that it is inevitable that it be a field for Federal interest, because certainly we do not know enough now to know that you can make rain and place it on one spot with accuracy. We certainly know enough to know that there is considerable probability that the attempt to do that may result in its being produced elsewhere, and it seems to me also that it is now evident that there are probabilities, at least, that rain making in one region may affect the rainfall at some distance. If that is the case, this thing seems to me inevitably to become a matter for Federal consideration and Federal control.

Senator LEHMAN. May I ask you a question?

Dr. BUSH. Yes, Senator Lehman.

Senator LEHMAN. Dr. Bush, there are now, of course, a great many different agencies of the Federal Government and the State governments and municipal governments that are deeply interested in this matter.

Dr. BUSH. Right.

Senator LEHMAN. They have, to a certain extent, conflicting interests and conflicting viewpoints. My very unconsidered judgment is that if this activity has the potentialties that you imply that it has, which I fully share as a layman, I believe that in time you are going to have to have a Federal agency, a single Federal agency, that will direct, encourage, and possibly even control experimentation, because of the conflicting interests and the diversity of the work.

Do you think that time has already come when it would be worth while setting up one Federal agency to do these different things?

Dr. BUSH. I think it has come, Senator. I think it is here; and, while I deplore complicating the Federal structure any more than it is now complicated, I do not see how this thing can be regulated properly by an existing agency. I think it needs one agency that is simple, as simple as it can possibly be made, for the purpose, for I believe that there has to be control in this matter.

I do not think the experimentation can be independent, with its variables controlled, unless there is some general regulation.

We do know certainly that this effort has a high probability of affecting considerable areas; so that, if there is indiscriminate experimentation, one piece of work is bound to affect another, and under those circumstances there has to be some central way of regulating it so that the experimentation will be systematic without, at the same time, excluding any competent group from experimenting privately.

I think it would be exceedingly unfortunate if today experimentation in this matter became centralized in any group whatever. I think we need competition.

Senator CASE. That is, in any existing group?

Dr. BUSH. Yes, in any existing group. For example, let me be very specific about that. I know that the Weather Bureau is quite skeptical on this matter. Many of the personnel are, at least. I think it is excellent to have a skeptic present, but I would not depend upon the Weather Bureau to do the experimentation in this field alone simply because from my experience in scientific investigation you do not get rapid progress except by having enthusiasts; and I would have, therefore, a situation in which the Weather Bureau could do its experimentation, but not exclusively.

Senator ANDERSON. You are speaking of some of the work you have done. A lot of that work has dealt with things ranging from proximity fuzes to atom bombs. Would you, without getting into the field of military science, think there is any possibility of any military significance to this work?

Dr. BUSH. Oh, it is much too early to tell, of course; and, if one can affect weather, well, then, it becomes of military importance, certainly, in small ways. For example, it might have been very nice indeed if we could have dropped a snowstorm at the Brenner Pass at the proper moment in the Italian campaign, but whether the proper moment and the proper meteorological conditions could have occurred at the same time is highly problematical at present. These things are bound to have military connotations. But certainly I see at the present time no clear pattern.

Senator CASE. But, Dr. Bush, right now observers of the Korean picture are calling attention to the fact that the rainy season is approaching in Korea, when it is anticipated that it will seriously affect our possible air operations over Korea, which may have some direct bearing on the course of the campaign.

Dr. Bush. I certainly think we are not in a position at the present time to change the advent of the rainy season in Korea very much.

Senator CASE. I did not mean to imply that, but what I meant to imply was since weather is such a large factor in military operations——

Dr. BUSH. Oh, yes.

Senator CASE (continuing). Obviously, if you get into this field, you might even on a local scale affect the particular impact of tactical air operations.

Dr. BUSH. That is quite right, Senator; but I like to think of this in a little different way. If it is possible to affect weather and to affect climate through affecting weather significantly, so that it can really alter the conditions for growing crops in a considerable region, then this country has an excellent opportunity—we have been in the lead in this science, very decidedly so—we have an excellent place in which to try it out, for we have in this country an extraordinary range of climate, and we have the scientists to do the work. If we can keep our progress growing in this, and if we can continue our lead in the scientific way, there will be an opportunity for us to contribute to other countries where climatical conditions are critical and difficult; and, by so doing, I hope, extend our favorable influence over the free world.

Senator ANDERSON. Are there any questions?

Dr. Bush, thank you very much. I appreciate your taking the time to come up and sit with us.

Dr. BUSH. I am glad to be with you.

Senator ANDERSON. Dr. Houghton, of the Department of Meteorology, MIT.

Dr. Houghton, those letters "MIT" mean a great deal with respect to a scientific problem, and we welcome you here. We are very happy to have you.

STATEMENT OF HENRY G. HOUGHTON, PROFESSOR OF METEOROLOGY AND HEAD OF DEPARTMENT OF METEOROLOGY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

Mr. HOUGHTON. I have a statement here. I am professor of meteorology and head of the department of meteorology at the Massachusetts Institute of Technology. I am also a member of the council and a past president of the American Meteorological Society. The opinions I express here are mine and do not necessarily represent those of the Massachusetts Institute of Technology nor of the society.

The subjects of cloud modification and the artificial stimulation of rainfall lie within that portion of meteorology in which I have specialized for 20 years. I have not been associated with any of the experimental projects on cloud seeding, nor have I had any connection with the commercial applications of cloud seeding. My interest in the scientific aspects of the problem has caused me to keep in close touch with the work and to undertake a careful analysis of the possibilities that rainfall may be increased by cloud-seeding techniques. This has led to the preparation of a paper entitled "An Appraisal of Cloud Seeding as a Means of Increasing Precipitation." This paper has been accepted for publication in a forthcoming issue—actually the February issue, which is not out yet but will be shortly—of the Bulletin of the American Meteorological Society. Reprints—or, really, preprints—of this paper have been made available to this committee.

In view of the availability of the paper, I will not burden you now with a complete review of my analysis. Instead I will present here, in somewhat different form, the principal conclusions which I have reached. This means, of course, my scientific conclusions.

1. The seeding of supercooled clouds with dry ice or silver iodide will usually convert at least a portion of the cloud to ice crystals.

2. The seeding of relatively thin, supercooled, layer clouds may open holes or channels in the cloud deck but little rain or snow will fall from such clouds.

3. The seeding of small, inactive cumulus clouds will usually result in the partial or complete dissipation of the clouds without the release of any significant amounts of rain or snow.

4. Seeding can effect the release of precipitation only from existing clouds. The requisite flow of moist air and the cloud-forming processes must be preexistent.

5. The weather conditions which appear to be most favorable for the artificial release of rain or snow are very much the same as those requisite for natural rainfall. For this reason it is extremely difficult to determine whether or not the results of a single seeding experiment are favorable. Scientific knowledge of the physical processes by which rain and snow are formed has not advanced to the point where it is possible to predict the results of seeding rain clouds nor to prescribe with any certainty the most favorable conditions for such seeding.

6. In my opinion there is a good possibility that the proper seeding of rain clouds may often result in the release of more precipitation than would have occurred from natural processes. There is no assurance that we know enough about the processes to seed such clouds in the proper way and it is quite possible that seeding will, in some instances, decrease the rainfall.

7. There is very little available evidence and no present scientific basis for the belief that we now have the ability to modify or control the large-scale atmospheric processes which are responsible for our general weather and climatic patterns.

8. Weather modification on a small scale, such as protection against frost and the local dissipation of fog and certain clouds, is known to be possible. Further research may prove that it is possible to reduce the incidence of hail, to reduce thunderstorm activity or to reduce rainfall, all on a local basis.

9. Definitive answers to the weather-control question can be expected to come only from further research. More knowledge is needed of the processes by which nature produces rain and snow. I would also favor a long series of seeding trials at a selected location with the experiment carefully designed from a meteorological and statistical point of view.

It will inevitably appear from these hearings that there is disagreement amongst the experts regarding the potentialities of cloud seeding. I feel sure that the members of your committee are accustomed to disagreement between experts. In science, as in government, conflict of opinions is common and is one of the means of progress. Ultimately, when all the facts are in, scientific disagreements are resolved. The present lack of agreement on cloud seeding is simply evidence that we do not yet possess adequate scientific information.

The bills which are under discussion all recognize the great potential benefits of weather control, particularly of the control and augmentation of rainfall. All of the bills call for further research. I strongly agree that research is the most important present need in this field.

S. 5 would authorize research in the Department of the Interior; S. 222 would provide a new commission which would be authorized to conduct research, and S. 796 would authorize the Soil Conservation Service and the Forest Service to conduct the research. Effective research in weather control requires personnel with training and experience in meteorology, cloud physics and statistics. There is an acute shortage of such personnel and essentially all of the qualified

people are now working in this or closely related fields. Adequate support appears to be available from the military departments for any worth-while research projects. The lack is not of money but of men. I note with some surprise that the one Government bureau concerned with weather science, the Weather Bureau of the Department of Commerce, is not directly charged with the research responsibility in any of the bills. The Weather Bureau possesses qualified personnel and the essential records. Establishing responsibility for weather research in other Government departments can only result in the draining off of qualified weather scientists from existing agencies without any increase in their total output.

Senator ANDERSON. Dr. Houghton, you heard Dr. Bush's comments on that. I wonder if you would amplify your comments on that, in view of what he said. You probably heard the testimony of the Weather Bureau?

Mr. HOUGHTON. I did not, Senator; I did not arrive until yesterday, but I have heard——

Senator ANDERSON. It was not rampantly enthusiastic——

Mr. HOUGHTON. I have heard about that.

Senator ANDERSON. To say the least. Dr. Bush suggests that the greatest progress might be made by people who had some slight enthusiasm in the field, as well as people——

Mr. HOUGTON. I agree, Senator.

Senator ANDERSON. Who are necessary in this world, who are strongly critical. We recognize that desirable trait.

Mr. HOUGHTON. I am not intending to imply here, and my later remarks will so indicate, that the research should be confined to the Weather Bureau. It was simply that I wished to point out that the bills which specify certain departments of the Government to have the responsibility for such research do not include the Weather Bureau in amongst those departments.

Senator ANDERSON. I must call your attention to the fact that S. 222, which is my bill, starts off with the Weather Control Commission composed of the Secretary of Commerce or his designee. We had put in there at the beginning the Chief of the Weather Bureau, and we were politely informed that you must name the head of the Department or his designee, and I remember then that I had had that same feeling when I was the Secretary of Agriculture [laughter], and we were only politely saying that they came into that category.

I hope that that did not mislead anybody, that it was not the Weather Bureau who was to assume full charge; but we were surrounding it by four people from private life who might have enthusiasm for it. I mean, if we were to start off now to pick a person to handle the project in South Carolina where we may happen to develop a hydrogen bomb we do know that several scientists have announced recently that it could not be built, on the theory that—I gather from your remarks, you would not really recommend, would you, taking those scientists who think it cannot be built and let them spend the $500,000,000 down there?

Mr. HOUGHTON. No, sir.

Senator ANDERSON. That is all we are trying to say. We would like to see somebody who thinks it can be done try to do it.

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Mr. HOUGHTON. My remarks, Senator, were concerned not so much with your bill as with the two other bills under discussion which do specify bureaus and departments.

Senator ANDERSON. I thought I ought to explain that the purpose of this bill was to bring the Weather Bureau into it, and I am sure that Senator Case did not mean by his bill to leave the Weather Bureau out, because he was concerning himself with the agricultural phases of this problem and felt that those properly came under the Department of Agriculture.

Mr. HOUGHTON. My real point, I hope you will understand, is that simply we have a shortage of qualified personnel.

Senator ANDERSON. Yes.

Mr. HOUGHTON. And if we set up within any agency, or as a separate agency, a group to work on this problem, we will have to take the men, or at least the keymen, from places where they are now being used.

Senator ANDERSON. I think it is a very important point.

Mr. HOUGHTON. Shall I proceed?

Senator ANDERSON. Yes, indeed.

Mr. HOUGHTON. In my opinion, the establishment of a Weather Control Commission as proposed in S. 222 is premature. It presupposes that we are on the verge of being able to exercise widespread control over the weather. As I have attempted to indicate, this assumption is still in question and the final answer must await further research. Suppose the answer is negative. With little to do the Weather Control Commission should then be dissolved but commissions are difficult to kill and tend to find ways to perpetuate themselves. Excuse my language.

Senator ANDERSON. You are not new to Washington, I take it. [Laughter.]

Mr. HOUGHTON. The creation of a Weather Control Commission now by the Congress would clearly imply that weather control on a rather large scale is an established possibility. The Atomic Energy Commission was the pattern for the Weather Control Commission. After Hiroshima there was no question about the importance of atomic energy but there has not been a similarly clear-cut demonstration of weather control. The security aspects of atomic energy can hardly apply to weather control since the basic information has already been disseminated.

Senator ANDERSON. I just hope, Dr. Houghton, that you are here Monday afternoon when Dr. Krick, who has signed up for 200,000,000 acres at the price of $200,000 in my home State, and I am sure he can tell there have been very clear-cut demonstrations of weather controls, and we should like to have you give us your scientific appraisal of his testimony after he concludes with it.

Mr. HOUGHTON. Senator, I regret that my duties at MIT will not permit my being here Monday. I have on other occasions heard a rather complete statement of Dr. Krick's, and I have attempted to keep in as close touch as possible with his operations, so I am not as completely unfamiliar with them, nor was I, when I wrote this.

Senator ANDERSON. In all seriousness, it would be helpful if we had it at some time—if we had an appraisal of some of these tests.

Mr. HOUGHTON. I have left with the committee as part of my testimony that which is really an appraisal of cloud seeding as a means of increasing precipitation. I would prefer not to be called upon to

appraise an individual's work. I have attempted to give an impersonal appraisal in this paper as completely as I thought I could now. The paper, I might add, although it is to appear in a scientific journal, contains no mathematics whatsoever, and I know that the members of your committee can read it with little or no difficulty.

Senator ANDERSON. Thank you.

Mr. HOUGHTON. A Commission would tend to control most of the research in its field. Particularly in a subject like this competition in research is as important as competition in business and a maximum of freedom in research is essential. In this, you see, I second Dr. Bush.

The provision for licensing in S. 222 strikes a responsive chord, although not exactly the one which Senator Anderson intended. The value of rain to the semiarid sections of our country has resulted in extensive commercialization of cloud seeding. To protect the public, it would seem desirable to require that commercial operators meet certain minimum standards of competence. For research purposes it is important to have records of the time and place of such commercial operations and of the kind and amount of the seeding material used.

Senator LEHMAN. Dr. Houghton, may I interrupt you?

Mr. HOUGHTON. Certainly.

Senator LEHMAN. You say that you agree that licensing is necessary——

Mr. HOUGHTON. I do, Senator.

Senator LEHMAN (continuing). And advisable. How would you proceed to license, unless you had some single agency, commission, or otherwise, to do it? I mean, otherwise you would have this competition from many different departments.

Mr. HOUGHTON. It is clear to me, Senator, of course, that licensing must be done by a central agency but not necessarily by a new agency. Many of the agencies of the Federal Government now issue licenses for various purposes. I, of course, am not an expert in these matters and would not think of advising the committee as to how the licensing procedure should be handled.

I agree, certainly, license must come from only one place.

Senator ANDERSON. Well, the purpose of the bill, that I introduced, at least, is not necessarily to set up a new agency. The purpose of the bill was to provide for the development and regulation of methods of weather modification and control. Now, if that should be in some other agency, that is the purpose of these hearings.

Mr. HOUGHTON. Yes, sir.

Senator ANDERSON. But when you label the bill as premature, and then in the next breath say that registration is required, and that standards need to be set up, then I wonder if you really believe that it is premature.

Mr. HOUGHTON. May I reread the sentence?

In my opinion the establishment of a Weather Control Commission, as proposed in S. 222, is premature.

Senator ANDERSON. I am sorry.

Senator CASE. But the provision for licensing you favor?

Mr. HOUGHTON. That is correct.

In conclusion I would favor a bill which included the following provisions:

1. Authorize the appropriation of funds for the establishment of a joint project to conduct a carefully designed series of cloud-seeding

experiments extending over at least a year in selected region. The agencies involved should include those Government departments and bureaus, both civil and military, which have a direct interest in either the weather or the utilization of precipitation. I might remark that we have had a similar arrangement in meteorology quite recently of the so-called thunderstorm project, which was such a joint project, and was eminently successful.

Senator ANDERSON. The one conducted near Hamilton, Ohio?

Mr. HOUGHTON. That was one of their sites of operation. The other was in the State of Florida. The first year they operated it in Florida; the second year in Ohio; not on cloud seedings, Senator, but studies of the thunderstorm. That, as I recall it, the Weather Bureau, the National Advisory Committee——

Senator ANDERSON. That is the work that Ross Gunn was doing? He was in charge of a project, is that the project you are referring to?

Mr. HOUGHTON. No. Dr. Horace Byers, of the University of Chicago, was in charge of the thunderstorm project. It was not concerned with cloud seeding; it was concerned with a study of the structure of the dynamics of the thunderstorm and was designed to improve our knowledge of the thunderstorm, both for forecasting purposes and for the safety of air transportation. I simply cite that, as an example of a joint project of the type that I am suggesting here, which did not involve the establishment of a new agency, but involved the cooperation of several existing agencies, all of whom were interested in the same problem from slightly different points of view.

Senator ANDERSON. I am now trying only to orient myself. It does not then refer to the cloud physics project?

Mr. HOUGHTON. No, sir; it does not.

Senator ANDERSON. It was called——

Mr. HOUGHTON. It was called the thunderstorm project. Funds were appropriated, I think, in this instance to the Weather Bureau by the Congress, it having been agreed that the Weather Bureau would request the funds for the entire project, but there were several other agencies involved in cooperation, including the Air Force, the National Advisory Committee for Aeronautics. So I just wanted to call that to your attention that this had been done and unsuccessfully in another instance, which had no connection with this.

Two, I repeat again, a provision for the licensing of private individuals or groups who desire to attempt to induce or control rainfall or hail on a commercial basis. Licensees should be required to demonstrate a reasonable degree of knowledge of cloud physics and meteorology. They should be required to furnish complete data on their operations. Protection against frost and the local dissipation of fog and low clouds should be exempted from the licensing requirements.

Senator CASE. Mr. Chairman, I think there is a point there that perhaps should be nailed down. You are suggesting then that only those operations which are on a commercial basis should be licensed?

Mr. HOUGHTON. Yes, sir.

Senator CASE. But that an individual, for instance, who wanted to dissipate the frost or a fog or seed a low cloud would not need to be licensed.

Mr. HOUGHTON. That is correct. My real reason for that, Senator Case, was this: For example, we all know that frost protection of

orchards and other crops is something that is done every day in various sections of the country; it is an established practice. It does not affect anyone else, and it would seem rather silly that we should require all the farmers who want to protect their crops to have a license. This is weather control true, on a small scale; so it should be an exemption.

Senator CASE. Here is a very pertinent illustration from a letter, dated February 24, 1951, which is from Marion N. Bruce, of McIntosh, S. Dak. He says:

> Frankly I am alarmed that too many individuals will get into this thing and spoil the deal without control. I likely will myself. After two very dry years I am on the verge of insolvency and crop failure would set me afoot. Law or no law, it would be a temptation. I am referring to the overseeding with the silver iodine—

he calls it iodine—

> method. I don't doubt enough silver iodine will be burned in the Southwest and Arizona to seed the world this year. Only a widespread program of education of the public will have a chance to stop it. We need more unhampered research but under some control.

I think that is a pretty practical approach to the problem.

Senator ANDERSON. That man should not go broke; he is a pretty sensible person. What he is referring to is what runs through my mind. You would not stop the instance, where I read the other day of one rancher in my State who has three silver iodide generators, and he has them in charge of sheepherders, boys who have had no schooling at all, to say nothing of any science in meteorology, and they are told that if the clouds start floating across there, to put the "hot spot" to it and start the silver iodide going.

Now, all three of those boys are pouring silver iodide into the clouds every time they see a cloud go by. You do not think they should be required to have any license?

Mr. HOUGHTON. Yes, I do. Perhaps my wording is not as it should be, but what brought this up, I suppose, was I suggested that certain activities should be exempted. What I had in mind were activities that are purely local and well established, have been going on for a a long time. I was thinking, as I said, of protection against frost, fog dissipation, like FIDO, which is installed now at one of the west coast airports. I do not see why we should bother to license those people.

Senator CASE. Would you exempt the seeding of a local cloud with dry ice?

Mr. HOUGHTON. No. When I said—I suppose I always have to talk like a meteorologist no matter what I try to write—I say, fog and low cloud sort of as one word, because strictly speaking a fog, to be a fog, should be on the ground, bottom. From an airline point of view, if the base of this fog, instead of being on the ground is 50 feet up in the air—and this often happens—that is just as bad as far as landing is concerned as though it went to the ground or almost as bad, not quite; and if they had FIDO, for example, at the airport, they would operate it under those conditions just the same as they would if the fog were down at the ground. So I say fog and low clouds, meaning that situation. Now, if I had just said "fog", that question would not have come up and, as I say, I do this automatically, because of my background.

Senator ANDERSON. We are only trying to get what you are recommending and your recommendation is there should be licensing for those individuals who are tempted to control weather by increasing rainfall.

Mr. HOUGHTON. That is correct, commercial operations.

Senator ANDERSON. Either where a man does it himself or has it custom-tailored.

Mr. HOUGHTON. That is correct. I wanted to distinguish between that type of operation, which is done in the end for commercial profit of some sort, from purely research investigations, because in my third point here I say complete freedom to conduct research in cloud physics should be granted to any agency, governmental or private, of established competence and reputation.

Senator ANDERSON. Any questions? Thank you very much. I think that is a very worth-while contribution, and I appreciate your giving us a copy of this paper, which I will read. I won't guarantee that I will understand all of it. I got into one the other day that for the first few paragraphs went over my head because of mathematical calculations.

Mr. HOUGHTON. There are no mathematics in this and I am sure you can understand it.

Senator ANDERSON. Thank you very much.

(The document referred to follows:)

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AN APPRAISAL OF CLOUD SEEDING AS A MEANS OF INCREASING PRECIPITATION

(Henry G. Houghton, Massachusetts Institute of Technology)

ABSTRACT

The results of cloud-seeding experiments are reviewed briefly and it is concluded that, taken alone, they do not constitute an adequate basis for a sound appraisal of the potentialities of the cloud-seeding techniques. An attempt is made to extend and supplement the observational evidence with the aid of existing knowledge of cloud physics and synoptic meteorology. It is found that significant amounts of precipitation can fall only from clouds which are continuously replenished. It is concluded that the thermal effects of seeding are seldom sufficient to stimulate the vertical development of a cloud. Since the activation temperatures of the artificial ice nuclei are believed to be higher than the activation temperatures of natural ice nuclei there is a possibility that seeding may advance the onset of precipitation or release precipitation from clouds which do not extend to the activation temperature of the natural ice nuclei. It appears that the seeding of clouds which are already releasing precipitation may either decrease or increase the total precipitation; an unequivocal answer is not possible due to the lack of pertinent information regarding natural precipitation processes. On the basis of the analysis of the physical processes and general knowledge of synoptic meteorology it is concluded that it is unlikely that cloud seeding will cause large-scale effects. Further research on cloud physics and cloud seeding is recommended.

INTRODUCTION

The tremendous economic implications of the artificial control of rainfall have led to overoptimistic statements in the public press and to ill-advised commercial applications of rain-making techniques by persons who do not possess the necessary technical qualifications. These events have been viewed with concern by all responsible meteorologists. It is unfortunate that much of the money which has been spent by public and private agencies in an effort to increase precipitation in specific areas has contributed so little to our scientific understanding of the

processes involved. Without adequate scientific information it is impossible to determine, with any assurance, the economic value of cloud seeding or to prescribe the most favorable conditions and procedures.

As in the case of all scientific research, the several groups and individuals who are working in this field have criticized each other's experiments and interpretations. This normal scientific interchange has been unduly accentuated by the glare of publicity which has caused some of those concerned to be more dogmatic than is justifiable in view of the present incomplete information. In the view of the public the meteorological world has been divided into believers and nonbelievers. This is an unfortunate and ridiculous concept. The fact is simply that the information at hand is not sufficient to permit an unequivocal conclusion regarding the possibilities of the artificial control of precipitation.

It is the purpose of this paper to assess the seeding techniques for stimulating precipitation on the basis of present scientific information and to point out the more significant gaps in our knowledge. The writer has not been associated with any of the research groups in this field but has kept himself informed through the literature and personal contact with many of the active investigators. For the sake of brevity and continuity no specific references will be made to papers and reports describing the results of seeding experiments. The summary of the results as required for the present discussion is well known to most readers. Those who wish to read the original accounts are referred to the excellent bibliography which was recently published [1]. It is not the intent of the writer to attempt to refute or support specific claims of individuals; rather it is proposed to survey the subject as impersonally as possible. Lack of complete information makes the inclusion of certain personal opinions of the writer inevitable.

METHODS AND RESULTS

Modern rain making owes its origin to the discovery by Schaefer [2] that the insertion of dry ice or any object colder than about $-40°$ C. into a supercooled water drop cloud converts the cloud to ice crystals. Later Vonnegut [3] showed that the same result could be obtained by introducing tiny crystals of silver iodide which are presumed to act as sublimation nuclei because of the dimensional similarity of the crystal lattices of silver iodide and ice. The mechanism by which dry ice forms ice crystals is still in debate as is the whole problem of sublimation nuclei but it is a demonstrable fact that either agent will convert a supercooled cloud to an ice cloud. Knowledge of the mechanism of ice crystal formation is desirable, however, for an estimate of the number of ice crystals created by a known amount of the nucleating agent.

The application of the nucleating agents to rain making is based on the Bergeron-Findeisen ice crystal theory of precipitation. According to this theory, all moderate to heavy precipitation is initiated by the appearance of a few ice crystals in a supercooled cloud. By virtue of the fact that the vapor pressure over ice is less than that over water at temperatures below freezing, the ice crystals grow by sublimation at the expense of the supercooled water drops. If the number of ice crystals is very small compared to the number of water drops, the ice crystals will become large enough to fall. After further growth by sublimation and collision they leave the cloud as precipitation elements. It was suggested that many natural supercooled clouds do not release precipitation because of a failure by nature to provide ice crystals. The use of the newly discovered methods for producing ice crystals in a supercooled cloud to initiate precipitation in such clouds was a logical step.

The reported results of cloud-seeding experiments have been quite diverse. In a vast majority of the tests there has been visible evidence of the transformation of supercooled clouds to ice crystals. It seems safe to conclude that the occasional absence of such effects has been due to poor observing conditions or to the choice of a cloud which either was not sufficiently supercooled or was already composed of ice crystals. Nucleation of stratiform clouds often leads to the production of "valleys" or "canyons" and occasionally to the formation of holes through which the ground may be seen. Holes seem to occur most often when the cloud deck is relatively thin. The effect of the seeding is observed to progress laterally from the seeding line, often reaching a width of 1 to 2 miles in 30 to 50 minutes. Precipitation in the form of virga is a common observation but only rarely does any precipitation reach the surface from stratiform clouds.

The observational evidence on the effects of seeding cumulus clouds is extremely varied. Again there is evidence that seeding converts the supercooled portions to ice crystals but observation is much more difficult. It appears that some

cumulus clouds dissipate when seeded, some are little affected and, occasionally, accelerated vertical development results. Reports on precipitation range from none to very heavy. It is extremely difficult to say whether the precipitation results from seeding or from natural processes independent of the seeding. Observations made in a few cases of the elapsed time between seeding and the appearance of the precipitation are reasonably consistent, suggesting a cause-and-effect relationship. The data suggest that small cumulus clouds are usually partially or completely dissipated by seeding. It appears that the seeding of more active cumulus clouds often results in virga or light precipitation and, very occasionally, in heavier precipitation. Claims have been made that the seeding of large cumulus clouds under proper conditions may lead to the development of widespread precipitation. Very few cases of this type have been reported.

Langmuir [4] has suggested that "warm" clouds, in which the ice nuclei can have no effect, may be induced to precipitate by seeding them with water. The injected water drops grow as they fall by colliding with the cloud drops. If the cloud is deep and wet with strong updrafts the drops may grow to such size that they will rupture. The broken portions might then be carried up in the updraft so that the process would become self-sustaining. The conditions requisite for the operation of this process are likely to be those which lead to natural precipitation. A few tests of water seeding have been made but results are still inconclusive. There is little question that injected water drops will grow by collision and fall out as rain but there is reason to doubt that the continuing process visualized by Langmuir can operate except in clouds which are ready to release precipitation from natural causes. Because of the lack of adquate tests of this method and the more widespread interest in seeding with ice nuclei, no further discussion of the water-seeding process will be undertaken here.

ARTIFICIAL NUCLEI

Taken by itself the observational evidence, reviewed very briefly above, does not constitute an adequate basis for a sound appraisal of the potentialities of the cloud-seeding techniques. It is the purpose of this paper to amplify and supplement the observational evidence with the aid of existing knowledge of cloud physics and synoptic meteorology. It is considered that both the laboratory and flight experiments prove beyond any reasonable doubt that dry ice and silver iodide will both convert a supercooled water cloud to an ice crystal cloud. The only necessary condition is that the cloud temperature be a few degrees below the freezing point. For silver iodide, Vonnegut [5] states that the maximum temperature is near—4° C.; dry ice has been shown to cause ice crystals to appear at—0.7° C. [6] but the temperature should be low enough so that there is an appreciable difference between the vapor pressures over water and ice. There is no reason to doubt that ice crystals will grow in a supercooled cloud. The size attained by the crystals is dependent on their number, the initial liquid water content of the cloud, the temperature and the depth of the supercooled portion of the cloud. It is an essential feature of the Bergeron-Findeisen precipitation theory that the number of ice crystals be small compared to the number of supercooled drops; otherwise the terminal size of the ice crystals would be of the same order as that of the cloud drops and no precipitation would ensue. There is no satisfactory information on the number of ice crystals produced by dry ice. The estimate of Langmuir [7] that one pellet of dry ice forms 10^{16} ice nuclei would imply concentrations of the order of 10^3 nuclei/cm.^{3} even if the nuclei produced by a few pounds of dry ice were distributed through several cubic miles of cloud. Quantitative estimates of the number of nuclei produced by silver iodide generators have been made but it is nearly impossible to estimate their concentration in the cloud after release. Atmospheric seeding experiments have resulted in the formation of precipitation elements with a wide range of seeding rates. The inference is either that a much smaller number of nuclei are formed than has been estimated or that there is a marked selective action such that only a small fraction of the nuclei become ice crystals. If the latter is true, the situation would be analogous to natural condensation in which only a small fraction of the total number of condensation nuclei become cloud drops. It is not intended to imply that overseeding is impossible, but it appears that this has seldom been an important factor in the seeding experiments which have been reported. When dry ice pellets are dropped the initial seeding is in a vertical plane from which the ice crystals appear to diffuse laterally. It would be expected that the concentration of "seeds" would be a maximum at the center and would decrease rapidly on either side. If overseeding occurs anywhere it should be found along the seeding line. There is no convincing evidence of overseeding in this region.

It may be concluded that it is often possible to release some precipitation from supercooled clouds by seeding them. The pertinent question is how much precipitation can be released in this way which would not fall from natural causes. If the answer to this is unfavorable, it is still important to know whether the time of release of precipitation and the total precipitation can be altered by seeding.

Unless the seeded cloud is replenished, the upper limit to the precipitation is determined by the total liquid water contained in a vertical column through the cloud. Measurements indicate that a liquid water content of 1 g./m.^{3} is rather a high value. If all of the water in a cloud 10,000 feet deep of this water content were deposited as rain, the total rainfall would be about one-eighth of an inch. This is clearly an overestimate since it is not likely that all of the water could be precipitated and some would evaporate before reaching the ground. Most clouds would contain less water than has been assumed in this example. It is concluded that, unless the cloud is continuously replenished, the precipitation released by seeding will be very light and the cloud will be partially or completely dissipated by the removal of its water. Stratiform clouds have released practically no precipitation when seeded, as would be expected in view of their small total water content.

THERMODYNAMIC EFFECTS

It is next in order to consider the ways in which seeding might stimulate the growth and replenishment of the cloud. The phase transformation induced by the seeding releases the latent heat of fusion and the latent heat of sublimation of the water vapor which sublimes as a result of the lower equilibrium vapor pressure over ice. The exact value of the resultant temperature rise of the air depends on the initial temperature, the air density and the liquid water content, but for a typical case it is of the order of 1°C. It is important to note that this heating occurs only in the supercooled portion of the cloud and that the temperature rise ordinarily increases with elevation. To be really effective the heating should occur in the lower part of the cloud and below the cloud base. Unless there is a temperature inversion of 1°C or more, the heating will produce accelerated vertical motion in the supercooled portion with a maximum near the cloud top. As a consequence, there will be horizontal inflow above the freezing level. It is probable that a small pressure fall will ensue with a correspondingly small horizontal inflow into the column below the freezing level. None of these effects will induce additional vertical motion below the freezing level since they do not provide buoyancy forces in the lower levels. Air cannot be "sucked" up but must be driven up by a force applied to each element of the air column. There will be a tendency for the supercooled portion of the cloud to separate from the portion below the freezing level. Unless the environment above this level is very moist and the lapse rate steep, it is doubtful that there will be any marked growth of the upper portion of the cloud. If there is to be an acceleration of the cloud development as a result of the heat released by seeding, a natural convective circulation must be active in the lower layers. If this natural convection has been terminated somewhere above the freezing level by a small inversion or a slightly stable lapse rate, the heat released by seeding may extend the convective activity upwards. This requires rather special conditions. It may be remarked that a temperature rise of 1°C in the upper portion of a cloud is not very impressive when viewed on an adiabatic chart. The evaporation of the solid carbon dioxide pellets will cause the cooling of the air through which they pass. This will cause localized subsidence but in view of the small amounts of carbon dioxide used this cooling will have little effect after the first few seconds.

An effect similar to the heating discussed above will result if the liquid water of the supercooled cloud is caused to precipitate. This removal of mass will result in an upward acceleration. It is easy to show that the removal of 1 g of water per cubic meter will cause the same vertical acceleration as a temperature rise of about 0.3°C. Note, however, that the falling precipitation will impose a downward acceleration on the lower levels of the cloud. This downward acceleration will increase as the precipitation elements grow in their fall through the cloud. It is believed that this downward force of the precipitation is partly responsible for the downdraft in a mature thunderstorm. The convective circulation in a thunderstorm is strong enough to maintain an upward motion in part of the cloud in spite of the downdraft. It is hard to see how the release of precipitation from a seeded cloud can increase the convective circulation.

It is reasonable to conclude that seeding only rarely will stimulate the vertical development of a cloud. In the vast majority of cases dissipative effects are to be expected. These conclusions seem to be borne out by the results of cloud-seeding tests.

ARTIFICIAL VERSUS NATURAL NUCLEI

The basic premise of the method for the release of precipitation by seeding is that there is often an insufficient number of natural nuclei of sublimation or crystallization present in supercooled clouds to initiate precipitation by the Bergeron-Findeisen mechanism. The regular existence of supercooled clouds in the atmosphere supports this assumption. Present knowledge of the concentration and properties of natural nuclei of crystallization and sublimation is incomplete. Supercooled clouds are much more frequent than ice crystal clouds down to about −10° C. to −15° C. At lower temperature ice crystal clouds become more and more frequent although supercooled clouds have been reported at temperatures at least as low as −35° C. Measurements of the number of ice crystals appearing in an expansion chamber by Findeisen and Schultz [8] have indicated that the first crystals appear in the neighborhood of −7° C. The number of crystals formed was found to increase slowly as the temperature was lowered. At a temperature variously reported to be from −32° C. to −42° C. a very large increase in the number of crystals occurs. Thus, this experimental evidence is in general accordance with the observed temperature distribution of supercooled clouds. The nuclei introduced by seeding are active at temperatures of circa −5° C. and below. It is well to point out here that it is not at all certain that ice crystals are a necessary prerequisite for natural precipitation. Moderate rain often falls from tropical clouds which do not extend to the freezing level. The mechanism responsible for such precipitation presumably can operate also in a supercooled cloud although the ice crystal mechanism is more effective if the ice crystals are present.

The vertical development of convective clouds is often terminated by an inversion. If the temperature at the top of such a cloud were below −5° C. but still not low enough to activate the natural ice nuclei, seeding might release rain which otherwise would not fall. From the prior discussion it is evident that the precipitation could be substantial only if the cloud were also deep and in active development. This is the most interesting case considered so far. It is difficult to estimate the frequency of occurrence of the requisite combination of conditions from the data that are available. Certainly many convective clouds are topped by inversions at a temperature level of between, say, −5° C. and −20° C. but how many of them remain in active development after they reach the inversion and in how many cases is there a lack of natural freezing nuclei? Even though it might not be possible to secure data on the freezing nuclei a well-designed observational program should help to answer these questions.

It is of interest to consider whether continuous seeding would be required to maintain precipitation in the case discussed above. It has been suggested that when snow crystals are once formed they shed tiny splinters as they fall, which then serve as very effective sublimation nuclei. If this happens, the process would tend to be self-perpetuating, after the initial seeding, as long as the circulation was such as to carry the splinters into the updrafts. Information on splintering is very incomplete and no definite conclusions can be drawn. It seems probable that the effectiveness of this process depends on the form of the snow crystals; the dendritic (feathery) type would appear to be a much better source of splinters than the columnar and tabular forms. It has been stated that natural snow often appears to fall from below the −10° C. level, thus suggesting that something like the splintering process is active. A more careful study of this might yield some useful clues, particularly if samples of the snow crystals could be obtained. If splintering does not occur, continuous seeding would be required.

SEEDING OF PRECIPITATING CLOUDS

It is next in order to consider the possibility that seeding will alter the timing or the total amount of precipitation which falls from a cloud which is about to release precipitation from natural causes. It is almost impossible to answer this by means of individual seeding experiments. An objective answer might be obtained by seeding all potential rain clouds over a well-defined area for a long period of time (a year or more) and then comparing the precipitation in the area to that in similar control areas. Even here, there are pitfalls and the experiment should be very carefully designed in advance by a competent statistician-meteorologist team.

Evidence has been presented above that the activation temperatures of the artificially introduced ice nuclei are higher than those of most of the natural ice nuclei. If an active cloud, which is about to release precipitation by natural processes, is seeded, the onset of precipitation may be advanced by the time

interval which would be required for the cloud to grow from the temperature level corresponding to the activation of the artificial seeds to that of the natural ice nuclei. The vertical distance between these levels might be of the order of 2 kilometers. The corresponding time interval might range from say 20 minutes for an active cumulus to a few hours for frontal cloud systems. This might provide a means for increasing the precipitation in a selected area from a given cloud even though the total precipitation from the cloud were not changed. The net increase of precipitation in a given area from a large number of clouds would be small because only a few of them would be in the proper stage of development as they approached the area. It is possible that the seeding would decrease the precipitation from the cloud by causing the precipitation elements to form at a lower level, thus decreasing the total water condensed in the cloud. It may be concluded that although the time of precipitation may be advanced it would be difficult to secure any practical advantage from this prospect except under very special circumstances.

Because of inadequate knowledge of natural precipitation processes it is not possible to make an unequivocal statement as to whether or not it is possible to increase the rainfall from a precipitating cloud by seeding it. Precipitation requires vertical motion and the consequent condensation of water vapor followed by a process which converts the condensed water vapor into larger elements which can fall to the ground. A "precipitation efficiency" might be defined as the ratio of the rainfall to the mass of water vapor in the rising current. An efficiency of 100 percent could be achieved only if all of the water vapor were condensed and all of the condensate were converted to precipitation. The "precipitation efficiency" can be considered as the product of a "condensation efficiency" and the efficiency with which the condensate is converted to precipitation elements. The condensation efficiency is determined primarily by how far the water vapor is lifted. The efficiency of conversion of the condensate to precipitation depends on the temperature at which the ice nuclei operate and on their number. The condensate which is not converted to precipitation finds its way into the downward circulation required by continuity and is evaporated. Seeding provides ice nuclei which are active at a lower elevation (higher temperature) than the natural ice nuclei. If there is an insufficient number of natural ice nuclei which are active at or above the lowest temperature in the cloud, seeding might increase the precipitation by reducing the amount of condensate which would otherwise be lost in the descending branch of the circulation (increase in the efficiency of conversion). On the other hand, if there is a sufficient number of natural ice nuclei which are active at temperatures found within the cloud, seeding may reduce the precipitation by causing the precipitation mechanism to operate at a lower level in the cloud where less of the water vapor will have been condensed (decrease of the condensation efficiency). Finally, if the splintering mechanism is a regular and effective natural means of nucleating clouds once precipitation has started, seeding will have no effect since splinters of ice are the best-possible ice nuclei. Lack of knowledge on the number and type of natural ice nuclei and on the importance of the splintering effect leave the answer in doubt. It is the opinion of the writer that a significant fraction of the condensed cloud water is often lost by evaporation in the downward branches of the circulation. If true, this suggests that the precipitation can be increased by seeding if the proper number of nuclei can be introduced in the right place.

It has been suggested that silver iodide nuclei may be effective at a considerable distance from the point of release. There is no doubt that the particles can be transported for considerable distances by the winds. The particles will diffuse laterally and vertically thus infecting an increasing volume of air with a corresponding decrease in concentration. It is not known with certainty how long the silver iodide particles will retain their nucleating ability. The chance that the nuclei will encounter the proper conditions is evidently increased by permitting them to diffuse and cover considerable areas. On the other hand this makes the task of assessing the results exceedingly difficult. There is little to gain from this technique at least until more adequate information is available on the effects of seeding individual clouds under carefully determined meteorological conditions.

LARGE-SCALE EFFECTS

The general conclusion reached so far is that seeding may induce significant amounts of precipitation only under rather special conditions which are very close to or identical with those which lead to natural precipitation. Suppose that these conditions are met and the cloud or clouds are seeded. Under the most ideal conditions the seeding may result in enhanced convective activity and the

release of precipitation. The amount of precipitation is limited by the large-scale horizontal transport of water vapor into the area. This can be increased only by the creation or intensification of a circulation of the size of a cyclone. There is no evidence that local convective activity will lead to cyclogenesis. In fact, widespread convective activity often breaks out in an area characterized by flat pressure gradients without any subsequent effect on the pressure distribution. It must be admitted that knowledge of the causes and mechanism of cyclogenesis is incomplete but there is evidence that changes in the upper troposphere and stratosphere are important. It is difficult to imagine any influence of seeding at these heights. This is consistent with other evidence which strongly suggests that the location of cyclogenetical areas is largely determined by the large-scale hemispheric circulation patterns rather than by local effects. If seeding increases the amount of precipitation it will also result in a proportionate increase in the latent heat released. If a substantial increase in precipitation could be produced over a large area the latent energy released would doubtless have an effect on the circulation pattern though not necessarily in the region of increased rainfall. Natural precipitation anomalies are much larger than those which might conceivably be produced by seeding but even in such cases the effect of the release of latent energy on the circulation is unclear. In any discussion of a net increase of rainfall over large areas it is important to remember that precipitation is only one segment of the hydrologic cycle. An increase in rainfall requires increased evaporation and a greater transport of water vapor. It may be concluded that there is little prospect that cloud seeding will produce large-scale effects in the atmosphere.

The hope that large-scale effects might result from seeding is based in part on the assumption that large segments of the atmosphere are often in a metastable condition such that a small impulse will suffice to release the instability. A logical corollary of this theory is that the point at which the activity will start spontaneously is indeterminate, but that a small artificial impulse may be sufficient to initiate the release of the instability at a predetermined point. If this principle of indeterminancy is correct, it sets a basic limit on the precision with which it is possible to forecast weather. Most meteorologists will agree that this principle often seems to hold in the development of such small-scale phenomena as thunderstorms and tornadoes. This may be due, of course, to the fact that the scale of these phenomena is small compared to the spacing of the observations. In the case of large-scale phenomena there is no real evidence in favor of the indeterminancy principle. To be sure, many errors are made in forcasts but these appear to be explicable in retrospect when adequate data are available. The motion of such disturbances seems to be continuous without the erratic behavior to be expected from the indeterminancy principle. Studies of the motion and development of cyclones strongly suggests a dependence on the large-scale fields of motion and temperature. These large-scale variations appear to be of much more importance than any small scale, accidental differences.

SUMMARY AND CONCLUSIONS

The principal conclusions reached in this paper may be summarized as follows:

1. Seeding of supercooled clouds with dry ice or silver iodide will convert the clouds to ice-crystal clouds if the temperature is below ca. −5° C.

2. Seeding of an inactive cloud will not induce an important amount of precipitation.

3. Seeding a cloud will not accelerate the growth of the cloud unless there is active vertical motion below the freezing level and the environment above the freezing level is moist and only slightly stable. Partial or complete dissipation is more likely due to the lifting off and drying out of the top of the cloud and the downward force exerted by the falling hydrometeors.

4. Seeding of an active cloud which does not quite reach the activation temperature of the natural ice-nuclei may release useful precipitation.

5. It appears possible to advance the onset of precipitation from a cloud which is about to precipitate from natural causes by seeding it.

6. The possibility of increasing precipitation initiated by natural processes by seeding cannot be determined because of incomplete information about natural precipitation processes. There is at least some possibility that the precipitation can be increased in certain cases.

7. The conditions under which it appears possible that seeding might cause, or increase, precipitation are almost or exactly the same as those required for the natural release of precipitation.

8. Inasmuch as the most favorable conditions for the augmentation of precipitation by seeding are almost or exactly the same as those requisite for natural precipitation, definitive results cannot be expected from isolated seeding experiments.

9. On the basis of present physical knowledge and synoptic experience there appears to be no prospect that large scale efforts can be produced by seeding.

In view of the above conclusions it is considered that attempts at the practical application of cloud seeding techniques to increase natural rainfall are premature. The entire problem is still in the research stage and any funds available should be devoted to research on the basic mechanisms involved. Useful research results cannot be expected from personnel without extensive training and experience in cloud physics and synoptic meteorology.

It is the opinion of the writer that not enough attention has been paid to the meteorological factors in most of the past cloud-seeding experiments. It is believed that this omission is in large part responsible for some of the diametrically opposed conclusions of certain workers in this field.

There are two general approaches to further research in this field: Full-scale experimentation with a properly designed experimental plan and adequate meteorological data; and, detailed studies of cloud physics, both in the laboratory and in the free atmosphere. If possible, both approaches should be prosecuted simultaneously. The second plan is less expensive than the first and promises more fundamental results. However, the full-scale experimental trials must be made in the end since a complete knowledge of cloud physics would still leave out some important meteorological factors.

In some quarters it is argued that cloud seeding has been a failure and that further experimentation is unwarranted in view of the high cost. It must be admitted that the high hopes of weather control proclaimed by the popular press have not been realized. Nevertheless the demonstration that several cubic miles of supercooled cloud can be converted to ice crystals with a few ounces or pounds of suitable material is extremely spectacular in the light of previous efforts to control meteorological processes. This should be sufficient to stimulate further investigation. It is quite possible that further fundamental discoveries lie ahead which will not be uncovered unless the research is allowed to proceed. It is indeed unfortunate that publicity and argument have clouded the immediate issue but this must not be allowed to obscure the long-range scientific view.

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Senator ANDERSON. May I just stop here and put into the record a telegram from the Powder River Weather Research Corp., William W. Smith, president.

It has been suggested that since we had reference to it that we incorporate in the record at this point the entire text of chapter 131 of the Session Laws of Wyoming, 1951, which declares Wyoming's sovereignity to its atmospheric moisture.

(The telegram and the session laws referred to follow:)

GILLETTE, WYO. *March 16, 1951.*

HON. JOSEPH C. MAHONEY,
Washington, D. C.:

The Powder River Weather Research Corp. went on record today as unalterably opposing Senator Anderson's weather-control bill. This organization embraces eight northeastern Wyoming counties and Powder River County, Mont. Your support in opposing this bill is solicited. Federal control not warranted at this time.

POWDER RIVER WEATHER RESEARCH CORP.,
WM. W. SMITH, *President.*

[Chap. 131, Session Laws of Wyoming, 1951. (Original Senate File No. 61; Enrolled Act No. 53, Senate)]

AN ACT To declare Wyoming sovereignty to its atmospheric moisture, to promote Weather Modification experiments, to provide for accumulation and evaluation of data relative to such experiments, and to protect life, property, and public interests from injurious practices

Be it enacted by the Legislature of the State of Wyoming:

SECTION 1. A. It is hereby declared that the State of Wyoming claims its sovereign right to the use for its residents and best interests the moisture contained in the clouds and atmosphere within its sovereign State boundaries.

B. It is hereby declared that although little is known regarding artificial weather modification, research and experimentation should be encouraged.

C. It is hereby declared that although the ultimate use of modification methods is speculative, the application of such methods should have proper safeguards and provide sufficient data to protect life, property, and public interest.

SEC. 2. There is hereby created a Board, to be known as the State Weather Modification Board. The members of the Board shall consist of the State Engineer, the Commissioner of Agriculture, and the President of the University of Wyoming or their designated representatives. The members shall serve on the Board without pay but shall be entitled to charge actual expenses incurred therewith to the Department by which they are primarily employed.

SEC. 3. The primary function of the Board is to procure, compile, and evaluate information relative to weather modification experiments and activities within the State boundaries. The term "weather modification" means changing, or controlling any of the weather phenomena by chemical, mechanical, or physical methods.

SEC. 4. It shall be unlawful for anyone to engage in weather modification activities except under and in accordance with a permit issued by the State Engineer. The State Engineer may issue such permit only upon the recommendation of the Weather Modification Board and in such form as prescribed by the Board.

SEC. 5. A separate permit shall be issued for each experiment or group of experiments within a specific period of time and shall be revocable by the State Engineer upon recommendation of the Board, in accordance with such procedure as the Board shall establish.

SEC. 6. Prior to the issuance of any permit the Board shall have issued a registration certificate to the person or persons requesting such permit. A registration certificate shall be issued only after the Board has considered and approved the qualifications and responsibility of the person or persons requesting a certificate. A registration fee of Twenty-Five Dollars ($25.00) per calendar year shall be charged for each registration certificate so issued. Registration fees so received by the Board may be used by the Board in paying part or all of its administrative expenses.

SEC. 7. The Board shall be required to demand and receive a written report, in such manner as it shall provide, covering each separate experiment or activity for which a permit is issued.

SEC. 8. Said Board is hereby authorized and empowered to receive and accept for and in the name of the State any and all funds which may be offered or become available, from federal grants or appropriations, private gifts, donations or bequests, or any other source, and to expend such funds for the expense of administering this Act, and for the encouragement of experimentation in weather modification by the University of Wyoming or any other appropriate state or public agency, either by direct grant, by contract, or other cooperative means.

SEC. 9. Nothing in this Act shall be construed to impose or accept any liability or responsibility on the part of the State, the Board, or any State officials or employees, for any weather-modification activities of any private person or

group, nor to affect in any way any contractual, tortious, or other legal rights, duties, or liabilities between any private persons or groups.

SEC. 10. Any person, persons, institution, or group engaging in a weather modification experiment without a permit shall be guilty of a misdemeanor and upon conviction subject to a fine not to exceed One Thousand Dollars ($1,000.00) or by imprisonment in a county jail for a period not to exceed more than one year for each such offense.

SEC. 11. This Act shall take effect and be in force from and after its passage. Approved February 19, 1951.

(See appendix for session laws of other States.)

Senator ANDERSON. Senator O'Mahoney, chairman of the Interior Committee, has asked that the following letter be inserted:

THE STATE OF WYOMING,
HOUSE OF REPRESENTATIVES,
Cheyenne, Wyo., March 16, 1951.

Senator JOSEPH C. O'MAHONEY,
Senate Office Building, Washington, D. C.

DEAR SENATOR O'MAHONEY: I read in the Rocky Mountain News this morning of a Senate subcommittee hearing on a rain-making bill introduced by Senator Anderson, of New Mexico.

According to the news story a Mr. McKinney of the New Mexico Development Commission testified as to evidence of a concerted plan on the part of special interests to avoid legal responsibility for their activities in the rain-making field. He criticized a bill in the New Mexico Legislature because it relieves them of that legal liability.

I was much interested in this story, because I was struck by the fact that in the recent session of the Wyoming Legislature there was a deep-rooted opposition by those who wish to conduct weather-control experiments in Wyoming to any definite commitment by them as to their financial responsibility. We passed a bill which in rather vague terms adopts a policy of encouraging rain-making experiments and sets up a State weather-modification board.

The sponsors of the bill were anxious to avoid stating that "responsibility" meant financial responsibility, in speaking of the requirements of applicants to conduct experiments. The bill left it entirely to the board to set up standards if it wished as to the qualifications and responsibility of applicants. I feel that it is bad law; it makes no requirement of a showing of financial responsibility of an applicant, either to show that he is answerable if he fails to fulfill his contract with the landowners or conduct any cloud seeding at all, or to show that he has resources to pay damages for injury to persons or property. It got by the legislature this way even though it is common knowledge that rain-making promotion is almost exclusively in the hands of a California group, none of whom are residents of this State. The Wyoming law fortunately does not go so far as the New Mexico bill granting them exemption from legal liability. The Wyoming bill was killed on third reading, but passed on reconsideration. I think it unfortunate that it was reconsidered.

From what the news story said, I should judge that Senator Anderson's bill may fill the gap left open in some of the State rain-making measures, in the matter of responsibility, and I would be much in favor of it, if it does.

I feel this point is rather important, and I am addressing a similar letter to Senator Hunt.

With kindest regards,

JAMES C. HUNTER.

Senator ANDERSON. That is first cousin to tidelands.

Senator CASE. State ownership of water; and the origin of water is a very vital issue in Wyoming.

Senator ANDERSON. We fought that, of course, with respect to control by the Civil Aeronautics. They said there the air above the airport belonged to them, too.

Senator CASE. The O'Mahoney-Millikin amendment in the Flood Control Act of 1944 has its origin in that concept of State rights in the origin of water.

Senator CORDON. Thank God it is in there.

Senator ANDERSON. For the roof States, the States like California, they do not cheer so enthusiastically.

Senator CORDON. But I am from Oregon.

Senator ANDERSON. All right, Mr. Harrison, will you identify yourself and your position, please.

STATEMENT OF HENRY T. HARRISON, JR., MANAGER, WEATHER SERVICE, UNITED AIR LINES, STAPLETON AIRFIELD, DENVER, COLO.

Mr. HARRISON. I am Henry T. Harrison, Jr., Denver, Colo. In view of the fact that I have been preceded by such distinguished scientists, I should possibly explain a little more in detail why I am here.

I am speaking as an individual, although I am a member of the National Council of the American Meteorological Society, and was recently appointed to a special subcommittee to draft a position for the American Meteorological Society on the whole subject of weather control, the other members being Professor Houghton, as chairman, and Dr. Sverre Pettersen.

The point is that my own claim to being in such company was that I recently participated in a series of hearings in Colorado, where I have offered my advice on the problem of drafting State legislation on weather control. I have been in the field of applied meteorology now for a period of 27 years, the first 11 years with the Weather Bureau and the last 16 with United Airlines, with 4 years out for military service during the war in the Air Weather Service.

I am presently manager of weather service for United Airlines at Denver; but I should like to ask to speak as an individual and not as a representative of the airline or the society.

Senator ANDERSON. Thank you.

Mr. HARRISON. I might say that I have worked, of course, with Professor Houghton in considerable detail on this whole problem and I am in full agreement, on the basis of my practical experience in the field, with everything he has said heretofore on the technical phases, and I thought it might be of interest perhaps for me to read the brief statement on the problems we encountered in Colorado in drafting a bill at the State level on this problem. Might I read this statement, Senator?

Senator ANDERSON. Yes, indeed.

Mr. HARRISON. My association with weather-control operations and problems has been chiefly limited to a local situation existing in Colorado during the past 6 months. When Commissioner of Agriculture, Paul Swisher, last October was directed by the Governor to investigate the requirements for weather-control legislation for Colorado, I volunteered my services as an adviser for the group which was set up to look into the problem. I continued to serve with the working group in that capacity until the final result of our efforts, House bill No. 251, was introduced in the legislature last January.

I have had no direct experience with efforts to increase precipitation artificially. I have attempted to keep myself informed on weather-control developments ever since the initial experiments by Dr. Vincent J. Schaefer and Dr. Irving Langmuir back in 1946 but am admittedly

no authority on the subject. My contributions to the Colorado working group consisted of offering my advice on legislative requirements based upon my fairly extensive background in the field of applied meteorology and climatology plus a superficial knowledge of weather-control operations and tests.

At the outset our problem was probably no different than that already faced by certain other States and now being considered at the Federal level. It appeared that the proper course for restrictive legislation would become self-evident if we could only agree on the approximate potentialities of artificial weather modification. To reduce the problem to its simplest form, all we had to do was to adopt one of the following premises as our base line.

Senator ANDERSON. May I stop you there to ask you to indicate the people in that Colorado group? Were they trained meteorologists and so forth? Would you name some of them?

Mr. HARRISON. It was quite a catholic group, Mr. Chairman. Under the direction of Commissioner of Agriculture Paul Swisher, there was Mr. A. W. Cook, local official in charge, with the Weather Bureau in Denver; Dr. Evans, dean of the department of engineering at Colorado, A. & M.; Mr. Chalmers, the State conservationist, also at Colorado A. & M.; Judge Clifford A. Stone, who sat in later at some of the hearings, chairman of the Colorado Water Conservation Board; and then I might say that the rain makers and their sponsors were amply represented. Dr. Krick attended several of the sessions.

Senator ANDERSON. Rain makers are generally in favor of State control and keeping the Federal Government as far away as possible.

Mr. HARRISON. Within limits; they like as little control as possible. That was the point of our dealing with them down there and, as I said, they had ample representation, both the Water Resources Development Corporation and several other associations.

Senator CASE. Judge Stone is also recognized as one of the leading exponents of State's rights in water matters, is he not?

Mr. HARRISON. I believe he is.

Senator ANDERSON. We invited Judge Stone to come here and testify if he wished. He has been before this committee in this room many times, but he did not feel that he wanted to come and did not find it convenient.

Mr. HARRISON. Judge Stone sat in on the last two hearings we had the 1st of January.

Senator ANDERSON. Go ahead.

Mr. HARRISON. 1. Weather modification is economically feasible on a large scale.

2. Weather modification is economically feasible on a local scale only.

3. Weather modification is not economically feasible.

4. Too little is known about weather modification to draw any conclusions.

If we could agree that No. 1 was the correct premise to follow, then it appeared reasonable that legislation should be enacted at the Federal level and probably in coordination with Canada and Mexico. If we agreed on No. 2, the answer was that restrictive legislation was needed only at the State level. If either No. 3 or No. 4 was accepted, then there were no requirements for restrictive legislation.

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Our Colorado group concluded that premise No. 2 should be adopted as our base line. Due consideration was given to the public stand taken by two eminent authorities in the field of meteorology and physics—namely, Dr. Langmuir and Dr. E. J. Workman—to the effect that significant weather modifications are possible on a very large scale. While there appeared to be a certain amount of circumstantial evidence to support such a position, these two scientists were nearly isolated in taking such a view. The preponderance of opinion among other eminent authorities took an entirely opposite view and one which was further supported by a series of governmental reports summarizing the results of controlled tests by the Weather Bureau and the Air Force on rain making and cloud-control potentialities.

Senator ANDERSON. Are you referring there to the test made in the cloud physics project which was under the charge of Ross Gunn?

Mr. HARRISON. Yes, sir.

Senator ANDERSON. Do you feel that Ross Gunn is enthusiastic about the possibilities of that sort of thing, or was he placed in charge of the project to, perhaps, demonstrate exactly what it did demonstrate? Did you take that into consideration at all?

Mr. HARRISON. I believe I did, sir; I believe I did.

Senator ANDERSON. You say the preponderance of opinion among other eminent authorities—you have heard Dr. Howell say that perhaps Federal regulation is needed; Dr. Vannevar Bush saying that, Dr. Langmuir and Dr. Schaefer and others; and I am just wondering who the authorities were that you said took an entirely opposite view. You had the commissioner of agriculture in Colorado?

Mr. HARRISON. Yes, sir.

Senator ANDERSON. And the soil conservationist out there.

Mr. HARRISON. Two representatives from Colorado A. and M., and the local official in charge of the Weather Bureau. Of course, I am referring here to what was available to us, Senator, at the time. Now, a great number of the statements——

Senator ANDERSON. Did you try to get anything other than that?

Mr. HARRISON. Yes, sir.

Senator ANDERSON. Rain makers down in my State have had meetings. If I am at Albuquerque, they have one in Roswell. If I am at Roswell, they have one at Duran. I am never able to get to where they are. I wonder if there is an opportunity for those who do believe that there might be some possibility of doing this to be heard? Was that point of view expressed by anyone, the point of view that there could be some national significance that these clouds might float across the State line, for example, by mistake?

Mr. HARRISON. Yes, sir. As a matter of fact, at that time that was considered, but even then we were quite uncertain as to whether or not any control was required even at the State level. There was even controversy as to whether or not any phases of weather control were possible, locally or otherwise; and, as to authorities, I might say that I considered Professor Houghton as one of the most eminent and most authoritative and most objective that I know of in this country. I was in frequent touch with Professor Houghton at that time. I had known him for a long time, and it was essentially, I think, on his recommendation that I took that stand and recommended that at that time we should follow the stand that weather control is feasible

locally, but that the evidence is not yet secure enough to assume that we are now on the verge of large-scale modifications.

Senator ANDERSON. Thank you.

Mr. HARRISON. For evidence of local weather controls of economic significance, the sources were more numerous although still mostly of an indirect and circumstantial nature. This was particularly true of rain-making results. In spite of the large number of projects conducted over the western portion of the country during 1949 and 1950 to increase natural rain and snowfall, the data acquired during these contract operations was seldom made available to the public but became the nearly exclusive property of the operators and the associations which sponsored them. For that reason, it appeared advisable to discount many of the seemingly extravagant claims being made publicly by the weather-control operators and certain of their sponsors. Published evidence of an authoritative nature left little doubt, however, about our ability to induce rain artificially in very limited amounts under certain conditions.

One eminent physicist and meteorologist, Dr. Henry G. Houghton, expressed the belief, after a detailed and completely objective study of the problem, that useful amounts of rain could theoretically be induced on a small scale under certain ideal conditions which would probably not occur very often. Another noted meteorologist, Dr. H. R. Byers, placed himself on record as believing that prevention of hail offered better possibilities perhaps than any other form of weather control. This contention was supported, indirectly at least, by reports released by the General Electric Co. and the Air Transport Association quoting cases wherein certain types of cumulus clouds had been dissipated artificially by seeding methods.

Senator CASE. I would like to ask just one question at that point. When you say the prevention of hail offered better possibilities, you mean from a technical standpoint or from a practical standpoint? I have in mind that it would be difficult ordinarily for one to know that hail was actually going to take place. You see a cloud, and the average man will say that it looks like there is hail in that cloud, but would you know in sufficient time that practically you could get into motion and work on the cloud or do you simply mean that if you were working on it you might dissipate the hail.

Mr. HARRISON. Senator, I will answer the first part of that question first. I am quoting here Dr. Byers from a Chicago round-table discussion early in 1950, in which they were engaging in a purely theoretical discussion of the potentialities of weather control, and I am certain, or at least I had the impression, that Dr. Byers was not referring to any actual tests or operations, but theoretically it appeared to him that the possibilities offered greater chance there than even in rain making or snow making.

Senator ANDERSON. When was this round table?

Mr. HARRISON. It would be the spring of 1950, sir; a year ago.

Now to answer the second question: There, of course, is one operation that I know of today in this country under contract for the suppression of hail. That has been in the Rogue River Valley of Oregon. It was conducted by an organization known as Weather Control and with Harvey M. Brandau and Eugene K. Kooser, who started operations in 1949 under contract with the pear growers in the valley.

The economy there is very, very largely centered around the growth of pears. These boys signed a contract and agreed to attempt to prevent hail from falling on the crop anytime during the season from April 1 until October 1. It was timely, of course, because the year before, 1948, five hailstorms had caused an estimated $3 million damage just for that one community, so these boys operated under contract during 1949, and no hail was reported in the valley by the Weather Bureau during that year.

The contract was renewed last year under approximately the same terms. They simply were to engage in cloud-seeding operations designed to prevent the fall of hail anywhere within a restricted limit covering that valley. Once again during 1950 no hail was reported at Medford by the Weather Bureau.

Senator CASE. Do you know what technique they used?

Mr. HARRISON. No, sir. I understand it is a trade secret, although I think a patent has been applied for.

Senator CASE. You do not know whether they used silver iodide or the dry ice?

Mr. HARRISON. I do not know. I do not think that they used either one, although either may have been used occasionally, but I do not think that is the——

Senator ANDERSON. Have you ever heard of any other compound being used, any other type?

Mr. HARRISON. Not for rain making or snow making or for hail work. I believe various chemicals have been used, again, in the nature of a trade secret, in connection with fog-dispersal tests.

Senator ANDERSON. When the first group of scientists came down to New Mexico and some tests were run down there which produced, or coincidentally several inches of rain fell—I will not say it was produced by seeding—they seeded, and within a short time several inches of rain fell. Did you ever hear of discussions of whether that was any substance other than dry ice or silver iodide?

Mr. HARRISON. No, sir; I never heard of that operation.

Senator CASE. I do not know the details, but someone was telling me the other day—I believe Senator Dirksen—he understood that the United Fruit Co, used dry ice shot from a gun to protect their banana crops from hail. Do you know anything about that?

Mr. HARRISON. That I had not heard of, sir.

Senator ANDERSON. You may proceed.

Mr. HARRISON. The Colorado group concluded, therefore, that it should proceed on the basis that certain weather controls were possible on a local basis; further, that it did not appear fair to assume that private groups could always achieve their weather alterations without hurting other groups or individuals in the same community. Against this contention, the rain makers and their associations argued that the problem could always be worked out at the community level on an informal basis, that restrictive legislation would stifle progress in weather modification. Strong objections were raised to the idea that licensed operators should make public the facts concerning the exact location of their operations, the dates and the purpose of each operation. The explanation on this was that insurance companies might

cancel their liability coverage if they were required to make such details public. The consensus of the working group, however, took the position that no legitimate enterprise operating on a community basis should fear the disclosure of such basic information.

Senator ANDERSON. I want to congratulate you on that conclusion. I wish we could get that same conclusion all over the country.

Mr. HARRISON. The outcome of the activities of this working group was that a Weather Modification Control Act was recommended which would set up a four-man weather control commission to serve under the administration of the commissioner of agriculture and include one member each from the offices of the following:

1. Commissioner of agriculture.
2. Colorado A. & M. College.
3. The Colorado Water Conservation Board.
4. The State irrigation engineer.

The more important functions of this commission would include:

1. Licensing of all private operations designed to modify weather phenomena.

2. Determination of areas in which each licensee would operate.

3. The obligation to secure periodic reports from the licensees on the details of all operations.

4. Authority to appoint an individual or group to evaluate the results of all such operations.

Under the commission would be established an advisory committee consisting of representatives from practically all walks of life in Colorado which would have the duty of recommending to the commission ways and means of performing its functions. Members of both groups would serve without pay.

It would be pleasing at this point to report that the legislature reacted favorably on this recommendation and was prepared to enact such a bill into law.

Unfortunately, such is not the case. I was informed on March 7, 1951, that the Weather Modification Control Act of 1951, now being considered by the Colorado Legislature as house bill No. 251, retains the original title but nothing more.

Thus ends my first lesson in the problems of State legislation.

Senator ANDERSON. Would you care to answer what organization or group it was that did the lobbying that killed off your bill?

Mr. HARRISON. No, sir. I frankly do not know what happened to it. I just got word of it before I left.

Senator ANDERSON. We are more fortunate in New Mexico. We know who killed it off.

Thank you very much. I think it evidences the fact that a group of sincere citizens can sit down to work the problem out. I don't agree with all their conclusions that they reach, but I think they did a reasonably good job, and it is too bad they did not have better success with their final outcome.

Thank you, Mr. Harrison.

I should like to insert a telegram from Hon. Dan Thornton, Governor of Colorado.

(The telegram follows:)

DENVER, COLO., *March 22, 1951.*

MILLS ASTIN,
Clerk, Insular Affairs Committee,
United States Senate.

Understand your committee currently considering scope and type of legislation to administer or regulate artificial nucleation. Wish to point out the potential importance of rain making in this area if such activity proves definitely scientific success and believe private enterprise should continue progress and research to prove possibilities of this new field. Colorado Legislature passed this week initial legislation to assist private and public research and development and to protect property and public interest from injurious weather-modification practices. Believed such regulation, if any found necessary, is proper State activity.

DAN THORNTON, *Governor of Colorado.*

Senator ANDERSON. I think, if we have a moment or two, I would like to put in the record at this time the report of the Bureau of the Budget on all three bills. As to sea water, there is a comment on that which is favorable to it. We will put the entire letter in the record at this point.

(The document referred to is as follows:)

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington, D. C., March 16, 1951.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Senate Committee on Interior and Insular Affairs,
Room 224, Senate Office Building, Washington, D. C.

MY DEAR SENATOR O'MAHONEY: This is in reply to your request of January 11, 1951, for the views of the Bureau of the Budget on S. 5, a bill to provide for the extraction of potable water from sea water and other saline sources, and in further response to a letter of February 26, 1951, from Mr. Mills Astin, chief clerk of your committee, in which he asked that we consider S. 5 in relation to two other bills, S. 222 and S. 798, which would provide for the development and regulation of methods of weather modification and control, and of artificially inducing rainfall respectively.

In his 1951 budget message, the President said: "Experience in recent years has shown that it may not be possible to meet the shortages of water, which are a threat in some areas, through our extensive water resources program. I recommend, therefore, that the Congress enact legislation authorizing the initiation of research to find means of transforming salt water into fresh water in large volumes at economic costs."

As there are no technical obstacles in producing fresh water from the sea and other saline sources such experimentation should continue, with particular attention to the whole matter of the economic feasibility of the project. Accordingly, it is the view of the Bureau of the Budget that authority should be provided to permit research into methods of extracting potable water from saline sources more economically than is possible under present processes.

On the other aspects of these bills, particularly those relating to the artificial induction of rainfall, and weather modification and control, the picture is by no means as clear. The principal difficulty, as we understand it, appears to be that the physical processes by which rain is formed and precipitated are not yet understood. Some of the foremost scientists in this field doubt whether there is sufficient experimental evidence to prove that precipitation can be successfully induced artificially. In our present state of imperfect knowledge the difficulties of "controlling" or "modifying" the weather would seem to be so great that any Federal program should be limited to research and the evaluation of existing knowledge and data. At this time, therefore, it would seem to us unwise, if not impossible, to attempt to settle the jurisdictional questions which the three bills raise. The Departments of the Interior, Agriculture, and Commerce all have responsibilities and programs which may be deeply affected by further developments in weather control and modification. For these reasons the Bureau has indicated that presentation to the committee of their views by all three departments and any other interested agencies would be without objection from this office.

In the light of information obtained in recent weeks, we feel that it would be appropriate for the several Federal agencies concerned to continue whatever work

they can under existing authorities and funds made available under those authorities. We are of the opinion that such further work as can be justified at this time can be carried on under the provisions of S. 5 as suggested for amendment by the Department of the Interior in its report. The authorities of that bill will permit full interdepartmental collaboration.

Finally, it would seem to this office that further information on attempts to alter weather conditions should be collected from whatever sources are available throughout the country and that such information should be presented to the Congress before legislative authorizations broader than those contemplated in S. 5 are enacted into law.

Sincerely yours,

F. J. LAWTON, *Director.*

Senator CASE. Mr. Chairman, might I suggest that last night I read that a Swedish inventor has worked out a method for the distillation of salt water, which he says will yield a ton—250 gallons—of fresh water at a cost of 2 cents.

Senator ANDERSON. We had a thousand gallons at $4.50 the other day, or something like that—no; what was it? A thousand gallons is a pretty high figure. We had better check into that.

We will have hearings Monday morning and Monday afternoon. We will have Mr. Davies, Dr. Sherwood, Dr. Hosler, and Mr. Fox in the morning, and Dr. Krick, and a motion picture in the afternoon.

Senator CASE. Mr. Chairman, would you be willing to add to that two witnesses from South Dakota who participated in some of our local experiments out there?

Senator ANDERSON. I would be very happy to, because I understand the young men persuaded the ranchers that it rained thereafter.

Senator CASE. One is the pilot.

Senator ANDERSON. If we can get enough people who have seen it rain after a seeding operation, it would be very useful, I would think. They will be permitted to come and testify.

Thank you all.

(Whereupon, at 12:20 p. m., the subcommittee adjourned, to reconvene at 10 a. m., Monday, March 19, 1951.)

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WEATHER CONTROL AND AUGMENTED POTABLE WATER SUPPLY

MONDAY, MARCH 19, 1951

UNITED STATES SENATE,
SUBCOMMITTEES OF THE COMMITTEES ON
INTERIOR AND INSULAR AFFAIRS,
INTERSTATE AND FOREIGN COMMERCE,
AGRICULTURE AND FORESTRY,
Washington, D. C.

The subcommittees met, pursuant to adjournment, at 10:10 a. m., in room 224, Senate Office Building, Senator Clinton P. Anderson presiding.

Present: Senators Clinton P. Anderson, Herbert H. Lehman, George A. Smathers, Guy Cordon, and Francis Case.

Also present: Mills Astin, Chief Clerk to the Committee on Interior and Insular Affairs.

Senator ANDERSON. The committee will come to order.

I think the first thing I should do is to read into the record a telegram from Dr. Krick, who is scheduled to appear this afternoon. It is addressed to Mr. Astin, the clerk of the committee:

> While east-bound for Washington aboard TWA flight 2 this evening I was called from plane at St. Louis, emergency telephone call which notified me of serious automobile accident, injuries to my niece and a subsequent shock suffered by my wife whom I had left behind in Denver. I have no alternative other than to return to my wife, who is not yet completely recovered from recent childbirth. Therefore, will you please give my apologies to Senator Anderson and the committee and tell him I will present a written statement at the earliest possible moment, or appear in person if the committee prefers. Please advise me in Denver which you desire.

I think, Mr. Astin, that you should perhaps advise Dr. Krick that if it suits him we will have him file a written statement, because we want to close up the hearings at the earliest possible moment, and then have a chance to look at the printed hearings and get additional suggestions and comments and proposals from interested groups.

The National Weather Improvement Association, whose headquarters is in Sterling, Colo., through its president, Harvey L. Harris, has submitted a statement showing its attitude on the proposed bill. I think I will just refer to a little bit of this because, theoretically at least and probably—actually I do not know—this National Weather Improvement Association includes great groups of people who in various States are trying to do something about artificial rainfall. I do take exception to a portion of that statement because it says, in paragraph 8:

> The national association will abhor any hasty legislation; and feels now, that without any notice to it concerning this hearing for March 14–17 that it has not had an opportunity to prepare for nor properly sit in on these conferences; and

that being a most interested party, in fact as may well be shown, it is the defendant party, not to have an adequate opportunity before the important Senate committee, goes to the very essence of our type of government.

Well, I could not quite understand that in view of the fact that this was submitted in a letter from their attorneys in which the attorney said:

Following our telephone conversation last week, I phoned Mr. Harvey L. Harris, of Sterling, Colo. Mr. Harris is president of the National Weather Improvement Association. I told Mr. Harris that he or a representative of his organization was welcome to appear during the hearings, but Mr. Harris stated that it was impossible for him, on such short notice, to leave Colorado.

I do not know how they reconcile the attorney's letter that they had more than a week's notice and invitation to appear, with a message saying they had no notice and could not appear, so I took the liberty of sending Mr. Harris a telegram on March 16, reading as follows:

Have read statement submitted from National Weather Improvement Association through Moyer & Shapiro, attorneys. Letter of transmittal from attorneys indicates they telephoned you inviting you or representative of your association to appear at hearings on weather-control bills but you found it impossible to leave. However, your statement asserts that association has had no notice concerning this hearing and no opportunity to prepare nor properly sit in on these conferences. How you can say that when your attorney admits you had opportunity to attend is more than I can understand but so that record may be completely clear this is official invitation to appear to testify and to discuss what you think should be involved in this legislation. We had planned to close our hearings Monday, March 19, but will reopen them at subsequent date to permit your representative to testify. When will he arrive? Wire reply.

And I believe that they may have a representative here today, but the only point I make is that we have no desire to foreclose any association or group of interested folks from testifying on these bills, and we will be happy to have statements filed if the people do not have an opportunity to get them here in time.

I think I will file the complete statement from the National Weather Improvement Association together with the letter from their attorney.

(The documents above referred to are as follows:)

MOYER & SHAPIRO,
Washington, D. C., March 15, 1951.

Mr. MILLS ASTIN,
Internal and Insular Affairs Committee,
Senate Office Building, Washington, D. C.

DEAR MR. ASTIN: Following our telephone conversation last week, I phoned Mr. Harvey L. Harris, of Sterling, Colo. Mr. Harris is president of the National Weather Improvement Association. I told Mr. Harris that he or a representative of his organization was welcome to appear during the hearings, but Mr. Harris stated that it was impossible for him, on such short notice, to leave Colorado.

He has, however, forwarded a statement which I enclose and which he respectfully requests be considered along with other material presented at the hearings.

Thank you very much for your courtesy.

Sincerely yours,

BERNARD K. SHAPIRO.

STERLING, COLO., *March 13, 1951.*

From: National Weather Improvement Association.
To: Senate committee hearing on the Anderson weather control bill.
Subject: Attitude of National Weather Improvement Association on proposed bill.

1. The National Weather Improvement Association, a nonprofit organization, was formed in January 1951 of 10 State associations which had been organized in 1950, and most of which had conducted cloud-seeding operations in 1950.

We understand that there are 15 new associations which have been formed or are in the process, which will request membership in the national association, and which will have cloud-seeding programs this year.

We are advised that almost 75 percent of the States of Colorado and New Mexico have been organized, and that groups are organized in Nebraska, Utah, Arizona, Kansas, Wyoming, Washington, and Idaho, in addition to the original 10 State associations which formed the national association; and it is estimated that these areas which are involved contain almost 3,000,000 people and over 300,000 square miles of territory.

2. All of these associations are locally organized and locally managed. All have been completely financed by individual farmers and ranchers and businessmen; and, until proven otherwise, all will be greatly opposed to any outside controls, management, attempts at financing, or legislative actions not warranted by proven facts. All are also nonprofit organizations.

3. The statement of policy of the national association includes among other aims: "We favor the development of proper and constructive regulations through legislative action as facts become available, so as to provide orderly and continuing progress in the field of weather development. We recommend against, however, hasty and ill-advised legislation without proper scientific background, believing that such a program is a common trust and should be developed in such a way as to provide the greatest good for all concerned."

4. The national association does not believe that any legislation should be enacted at this stage of the development of the cloud-seeding programs because there is no one, and we believe that there is no one, who can, or should be allowed to prejudge any results at this time. Neither is it possible to evaluate any results now.

5. The national association does not believe that there are two technical scientists in the United States today who would concur in an answer to any given set of facts. How much more foolish then would it be to attempt to set up any code or series of regulations on the general subject?

6. The national association believes that it would be most constructive not to attempt any legislation now, but rather to wait for the final results of this season's programs, throughout the West, where the above-noted associations have been organized; that, if any results become detrimental to the localities, the local organizations would in self-defense and self-preservation police such untoward results more effectively.

7. The national association believes a very intelligent understanding will result from such a study of this season's operations; and that, since nothing is to be gained by any immediate legislation except to muddy the waters, a small commission appointed 50–50 by the president and local groups, made up of leading scientists, meteorologists, and members of the various local associations who shall study and evaluate 1951 results and submit suggestions for controls as might be necessary * * * to be passed into law in 1952; except that—

> Such laws shall begin at the State level, and to the maximum kept at that level; unless and until, and only when, national controls become obligatory * * * and then these shall become problems for Federal legislation.

8. The national association will abhor any hasty legislation and feels now that, without any notice to it concerning this hearing for March 14–17, it has not had an opportunity to prepare for nor properly sit in on these conferences; and that being a most interested party—in fact, as may well be shown, it is the defendant party—not to have an adequate opportunity before the important Senate committee goes to the very essence of our type of government.

10. The national association does not believe that any such elaborate or unwieldy agency as is contemplated by the Anderson bill is at all necessary at this time. It would merely be a case of the blind leading the blind to the extent of $250,000 or more for the year 1951; whereas a small commission (see par. 7) would accomplish everything contemplated by the bill; and that it is a useless and unnecessary Federal expenditure.

12. The national association cautions the committee in accepting as "unquestioned and 100 percent correct" the conclusions of any technicians at the hearing, or leading scientists who may be world famous in their respective fields, if they are not at the same time meteorologists of the same degree of perfection. Meteorology is a new field. There are few who know its intricacies. There will be such leading men of science at this hearing; and yet, whether admitted or not, there will be few who will honestly qualify as meteorologists.

Not having had sufficient, or any official, notice of this hearing the national association therefore requests that this statement be considered, read, and handled

by the committee as though it were being personally presented by a member of the association; and the association prays that, in view of the above-outlined thoughts which go to the essence of good sound judgment, no legislative action as completely theoretical as the proposed Anderson bill be passed at this session of Congress.

Respectfully submitted.

NATIONAL WEATHER IMPROVEMENT ASSOCIATION,
HARVEY L. HARRIS, *President.*

Senator ANDERSON. At this time we have a statement from the Mechanical Equipment Co.

(The letter above referred to follows:)

MECHANICAL EQUIPMENT CO., INC.,
New Orleans, La., March 17, 1951.

Subject: Statement for Committee on Interior and Insular Affairs of United States Senate.

Mr. MILLS ASTIN,
Chief Clerk, United States Senate,
Committee on Interior and Insular Affairs.

DEAR SIR: This statement is being furnished in connection with investigation of the possibilities of increasing the potable water supply of the United States by conversion of sea water. It is understood that legislation which would provide funds for further research and development in connection with producing potable water from sea water is being considered. As manufacturers of the most efficient machines to accomplish the above purpose in existence in the world at the present time, and as manufacturers of the largest capacity units for this purpose in existence, we feel that we are able to provide facts which will be of interest to this committee.

First, we must make the statement that we produce a highly efficient design of thermocompression water-distillation plant which produces very pure distilled water, excellent for drinking and other purposes. These machines are entirely practical and dependable and have demonstrated their ability to provide pure drinking water on an over-all cost, including depreciation, maintenance, salary of operator, fuel, etc., at less than the actual over-all cost of the water now being used by many towns and cities.

These machines produce pure distilled water at an over-all cost of $100 per acre-foot.

The current largest machine in use is 50,000 gallons per day output in one single machine. (One or two installations have been made by others, but they consist of smaller units in parallel and are not actually a single unit of this capacity.)

The efficiency of a thermocompression unit is at a maximum at the beginning of the cycle when the heat-transfer surfaces are clean and gradually decreases to a minimum at the end of the cycle when the scale is chemically removed and the cycle started again. Therefore, if the heat-transfer surfaces can be kept clean, the unit will operate almost at its maximum efficiency, which is presently very much above its average efficiency, and thus the fuel bill will be greatly reduced. The average capacity would likewise be increased by about 10 percent. The cost of the chemicals to remove the scale periodically would be eliminated.

It is estimated that a simple effective nonscaling arrangement would enable these machines to produce pure distilled water from the sea at a figure of approximately $85 per acre-foot.

This company has under development two methods of eliminating scale. The test on one of these methods is practically completed and it has already proven itself 100 percent satisfactory, and we expect to have it in commercial use within 30 days. The other method has proven satisfactory, but requires more expensive metals, so will probably be abandoned, since the first method is 100 percent satisfactory.

The question will probably arise as to how large these units can be built, and we believe that it would be practical to build a unit having the capacity of 250,000 gallons per day. For cities which require millions of gallons of water per day, a battery of such units would be required.

It would be interesting to note that we already have plans for building a number of 100,000-gallons-per-day output units.

The purchase cost as well as the maintenance cost could undoubtedly be further reduced by certain development work. Some of the best means of

accomplishing this are already in our company research program. Availability of funds for research naturally necessitates a staggering of the various investigation programs and means that it takes more time to bring about the eventual end result.

Should money be made available by the Government for research along such lines, we feel certain that we would be able to provide machinery to produce fresh water from the sea at much less cost than the figures given above.

Cities now getting water from aqueducts, such as Los Angeles, are using water, the over-all cost of which is very considerable. The taxpayers of the entire United States are generally contributing to the cost of local water in such places, and, therefore, should be interested in providing a more economical means of getting pure water from the sea for the various localities that are short of water. Consideration will also undoubtedly be placed upon the military advantages of individual water supplies for such cities due to the vulnerability of dams and aqueducts supplying numbers of cities and communities with water.

We believe that the above should supply the general information that would be interesting to this committee; if further information is desired, we will be pleased to forward same immediately.

Yours very truly,

MECHANICAL EQUIPMENT CO., INC.,
J. E. POTTHARST, Jr.

Senator ANDERSON. We have a statement from the World Water Co., Inc., of Phoenix, Ariz. I think we will just let the record show that there is a communication from them because this relates largely to desalting the Gulf of Mexico.

A statement from Olin S. Proctor is also in receipt. I think we will file his letter in the record.

(The letter from Mr. Proctor is as follows:)

LONG BEACH, CALIF., *March 8, 1951.*

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
Washington, D. C.

DEAR SIR: Responsive to your communication of February 28, re Senator O'Mahoney's bill, S. 5:

I shall not be able to attend the hearings, but am glad to have the opportunity to file a statement on this important matter.

I believe you have a copy of my booklet, Patents, Plans—Philosophy, in which pages 45 to 49 deal with my plans for ocean water recovery in Imperial Valley to the top of Mount San Jacinto. Just in case you do not have the booklet, I am enclosing these pages from which you may read selected portions into the record. In addition will say:

Location is the first consideration of any project. The situation of Mount San Jacinto is ideal for big scale ocean-water recovery but it may be deemed advisable to make a pilot or experimental plant first, on a small scale. I also know of such place about which I wrote Secretary of the Interior, Oscar Chapman, in November 1949, as follows:

"I have found an ideal situation for a pilot plant for ocean-water recovery. It is the 320 acre ranch of Mr. C. R. Spooner, adjacent to the Mexican border, about 2 miles from the ocean. Most of this acreage is occupied by a flat top hill about 400 feet above sea level.

Mr. Spooner is now electrically pumping irrigation water from wells in the valley at the foot of the bluff. He said they told him it was impractical to pump irrigation water more than 100 feet. He has been there over 5 years and seems to be making a good living raising beans, peas, peppers, egg plant, etc. He has a concrete-lined reservoir, 50 by 100 feet by 10 feet deep into which he continuously pumps 300 gallons per minute—which he says is more efficient and economical by eliminating stand-by expense and giving better production from the well.

There is an abandoned gravel pit at the foot of a gulch, with southern exposure, which would serve as ocean-water evaporation reservoir. About 1½ miles of pipe would be required to bring ocean water from a channel or slough. The cover of the saturation reservoir may extend to the top of the gulch, thus using it as a conduit. Blowers or fans may be advantageous in or near the condensor to increase velocity and condensation by pressure.

Another very important consideration is that Mr. Spooner evidently is a man of wide experience and engineering ability; he is vitally interested, and he has confidence in the project.

OLIN S. PROCTOR.

(The attachment referred to, being pages 45 through 49 of printed pamphlet entitled "Patents, Plans—Philosophy," reads as follows:)

OCEAN WATER RECOVERY IS ESSENTIAL TO FURTHER DEVELOPMENT OF SOUTHERN CALIFORNIA AND ARIZONA

With localities here and there over the globe now actually utilizing ocean water—also, power and minerals for both home and industrial use, adapting and improving methods developed of necessity during the last war, it may be very well for southern California, and her neighbor, Arizona, to start planning and working to get unlimited ocean water. To date, I have heard of no other ocean water program as simple and offering to harness natural forces so effectively as my own plans. To put my proposal simply, it is just this:

1. Dig a gravity-flow canal from the Gulf of Lower California to the wide flats of Imperial Valley, south and west of Salton Sea, well below sea level.
2. Spread out this gulf water in shallow vats over a great area and cover them with some thin metal so the heat of the sun will cause evaporation.
3. Control the rising currents of vapor by a system of conduits all converging into one large conduit excavated in the mountain—say to the top of Mount San Jacinto, over 10,000 feet high, where colder air will condense the vapors into a big reservoir of distilled water.
4. From this reservoir system, high on the mountain, the water can be channeled down through a series of hydroelectric plants, and on down to our valleys and cities here on the coastal plain, or over eastward to central Arizona.

Since the job of getting water from the Gulf of Lower California to the saturation plant by gravity flow is relatively simple, also getting the condensed water from the mountainside reservoirs over west to the coastal plain and east to central Arizona, we feature herewith a drawing to visualize the key step of vaporizing the ocean water when spread out in a saturation system under the focus of the intense Imperial Valley sun.

This water saturation plan is adapted for operation by gravity on hill slopes between ocean canal level and Salton Sea for removal of part of the water, leaving enough to carry the salt and other minerals into the Salton Sea. Circulating ventilators for water reservoirs would be used in conjunction with conduits of sufficient height to make suction. or clear to the top of Mount San Jacinto. This would reduce Salton Sea to "mother liquid," which would be refined by numerous chemical plants in the surrounding country.

There are about 250 square miles in the Salton Sea, and there must be about the same area around the western rim of Imperial Valley between the ocean level and the sea itself.

The noted astronomer, George Gamow, in Birth and Death of the Sun, 1940, says the flow of solar energy to the earth is 4,690,000 horsepower per square mile. So any system capable of recovering any small fraction of this astronomical amount of power would make Hoover Dam power plant look like a toy. And the volume of water this available area under terrific direct sun rays with a forced draft the hot air could produce would make the metropolitan aqueduct look like a small brook.

In my investigation of this subject during the past 20 years among experts and others, it appears that the heat in the air has not been considered. I am inclined to think this unlimited volume of hot air is a far more available source of energy than the direct sun rays, on which many thousands of dollars have been spent with no practical results.

Briefly, here are some important points why this project should interest you and the whole world:

1. Water produced will be pure, distilled, at high elevation, available for power, irrigation, and domestic use.
2. Operation will be automatic with minimum maintenance.
3. Capacity may be increased as required.
4. Salt and mineral recovered would liquidate installation.
5. The world-wide interest and importance of the project would have great economic value.
6. Additional water and fertilizer will affect soil conservation.

We know a great volume of air must be handled to produce any considerable amount of water; but we also know the air moves automatically and the supply is unlimited. So capacity is only a matter of conduit diameter. Preferably or practically, the only way to get a conduit of sufficient capacity would be by excavation in the mountain. With modern methods this would not be too expensive and it would be permanent. And could be increased as required by enlargement or additional units.

I am retiring, but hope to live long enough to see my ocean water recovery project in operation in Imperial Valley and on Mount San Jacinto; proving my contention that the heat in the air, in semitropical regions, is a secondary source of solar energy, comparable to coal, wood, oil, and electricity, into which it is readily converted. Regardless of many expensive efforts to use direct solar heat alone, this has proven impractical. I propose combining direct solar heat with heat in the air to hasten air saturation and distillation of ocean water on a large commercial scale.

CONSTRUCTION AND OPERATION OF OCEAN WATER SUPPLY

The essence of this problem is to get action of solar heat on large areas efficiently and economically. This can be done by a great number of covered reservoir units, preferably about 10 by 100 feet by 1 foot deep, with covering in sections 3 by 10 for convenience in making and handling. Grading would be done in strips a mile or so in length; then the reservoirs would be formed by concrete walls 1 foot high, 100 feet long with 10 feet cross walls or ends. In this construction one wall serves two reservoirs except the outside ones. A lateral conduit would cross the system each 200 feet and connect with the main conduit. Generally, the system would run east-west. The top of the intervening walls would have 6-inch steps formed on the north side so the north end of the covering sections would be 6 inches higher than the south end, making a saw-tooth effect which can be varied to suit the contour of the ground. It also affords suitable location for air admission down through the wall to discharge against a lip just below water level so water will be blown up against bottom of the cover. Water to supply the lip should come up through the wall from near the bottom, so control of air admission and water to meet it makes a spray to facilitate saturation of the air.

Operation: Heat on this vast surface expands or rarifies the moist air backed by 15-pound air pressure so it travels through the conduit to discharge in 11-pound pressure on top of Mount San Jacinto where it is cold causing contraction and precipitation. So the operation is completely automatic with air the only moving part. When installed the only expense would be adjustments and maintenance.

Salt and other chemicals have paid for use of large areas to evaporate ocean water by simple exposure. By enclosing the reservoirs and using the heat energy acting on the enclosed air, circulation is produced to increase evaporation and save the water and power. So this project should pay off big in three ways, chemical, water, and power. Off hand, I imagine 1 square mile of surface may be required for a 50-foot conduit. There should be plenty surface to get good action on the conduit.

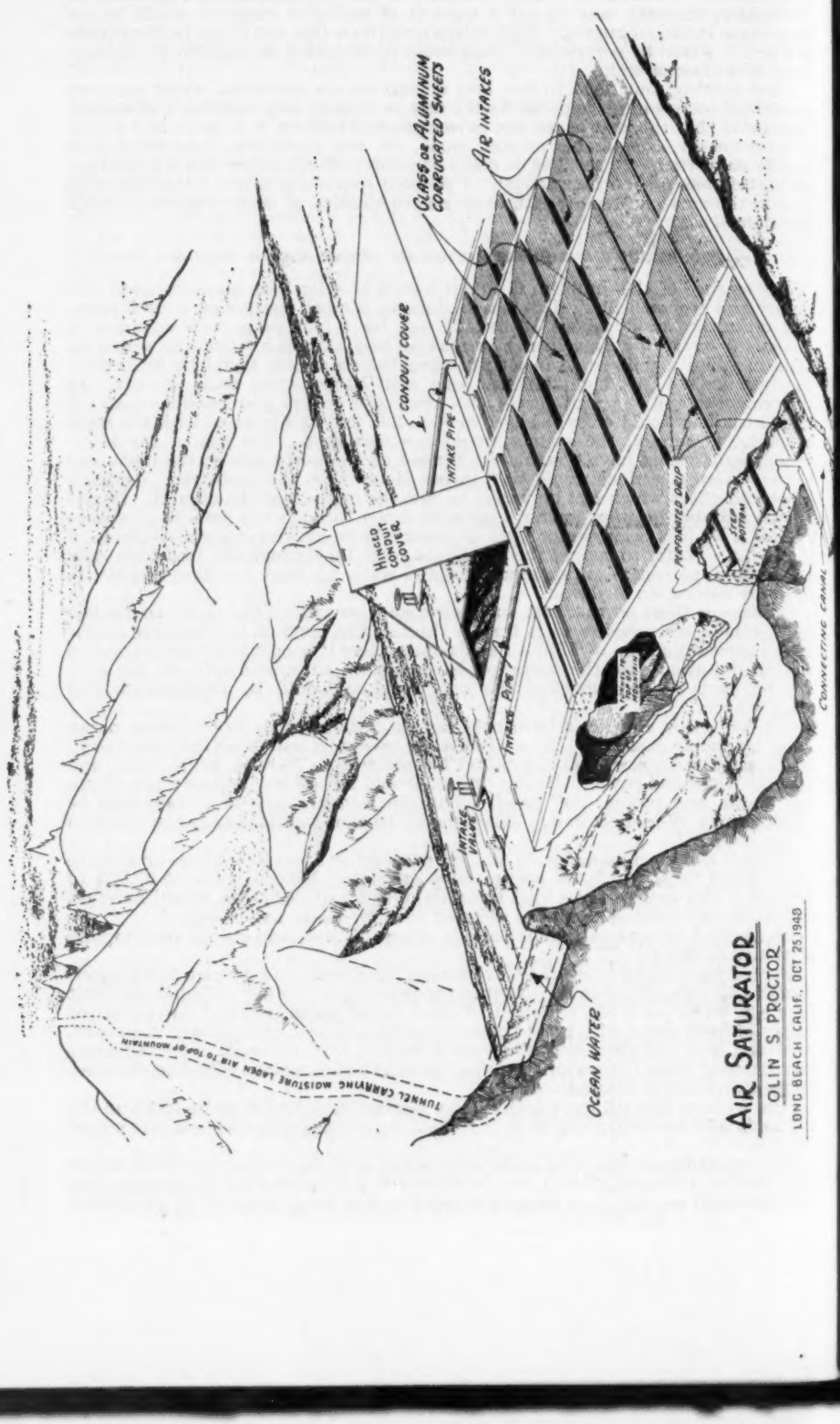
The salt and chemicals of such amount of water as Long Beach uses amount to about 2,500 tons, which, at conservative estimates, have a value of $7,000 to $10,000. The uses of these vast amounts of salt and chemicals would build an empire, to say nothing about the pressing need for water and power.

I have filed no application for patents along this line, and do not contemplate filing any at this time.

I would be satisfied to see the Government investigate and develop this project, though this thought, idea or invention, apparently is the key to separating salt from sea water on a big scale with billion dollar potentialities. An unlimited supply of fresh water with great power potential and vast quantities of chemicals, combined with the great known stores of copper, iron, and coal in the adjacent mountains of Utah, Colorado, and other States in fertile regions with fine climates, staggers anybody's imagination.

I am waiting now till the United States Government makes up its mind on the tidelands issue before putting or trying to put my ocean-going drill boat into actual practice.

The air saturator plan is so gigantic in detail, and the expense involved to put it to work so immense, that it may be years before a corporation or company will have foresight enough to go ahead and build it, and bring bloom to all arid desert


GLASS OR ALUMINUM CORRUGATED SHEETS
AIR INTAKES
CONDUIT COVER
INTAKE PIPE
REINFORCED CHUTE
CONCRETE COVER
INTAKE PIPE
INTAKE VALVES
TUNNEL CARRYING MOISTURE LADEN AIR TO TOP OF MOUNTAIN
OCEAN WATER
CONNECTING CANAL
AIR SATURATOR
OLIN S PROCTOR
LONG BEACH CALIF. OCT 25 1948

wasteland. I do not have the millions it would require to put this over, but hope to live long enough to see it put to practical use.

I hope my patent information has been submitted in such a manner as to prove instructive and interesting to readers. Based on this long and wide experience I conclude: What this country needs is not another 5-cent cigar nor another cocktail bar; but it does need some new faces in high places.

O. S. P.

Senator ANDERSON. Senator Case calls my attention again to this item about the Swedish inventor who is developing a new machine able to convert salt water into pure drinking water for 2 cents a ton.

Senator CASE. I am not vouching for that, Mr. Chairman.

Senator ANDERSON. I think we would be very derelict in our duty in looking at this bill if we did not pay attention to a thing of that nature.

Senator CASE. It is an item reported in Quick Magazine, which I thought warranted reference.

Senator ANDERSON. It certainly does. I think if Mr. Astin, the clerk of the committee, would ask Quick for such additional information as it has on that, it would be useful to us.

(See the following inserted correspondence:)

MARCH 21, 1951.

Mr. WARREN PHILLIPS,
Chief of the London Bureau, Wall Street Journal,
London, EC4, England.

DEAR MR. PHILLIPS: Recently this committee has been engaged in hearings having to do with weather control and the extraction of potable water from sea water.

Our interest was attracted by your London cable of March 5 reporting that a Swedish scientist, Baltzar von Platen, had developed a process whereby he could convert sea water to fresh water at a cost of 2 cents per ton.

The committee will greatly appreciate any additional details which you may be able to furnish. I secured your name and address from Mr. Haller of the Washington office.

Yours sincerely,

MILLS ASTIN, *Chief Clerk.*

THE WALL STREET JOURNAL,
New York, N. Y., April 9, 1951.

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

DEAR MR. ASTIN: Mr. Phillips has referred to me your letter of March 21, and I am sorry for the resultant delay in communicating with you.

We are not in a position to provide any further details on the process of Mr. Baltzar von Platen for converting sea water to fresh water. However, I have Mr. Von Platen's address and suggest that you write him directly.

The address is the following: Baltzar von Platen, c/o Electrolux, Inc., St. Eriksgatan 63, Stockholm, Sweden.

I hope that this will prove of some assistance to you, and wish to thank you for the interest you have shown.

Sincerely yours,

JOSEPH E. EVANS, *Foreign Editor.*

APRIL 30, 1951.

Mr. BALTZAR VON PLATEN,
Care of Electrolux, Inc., Stockholm, Sweden.

DEAR MR. VON PLATEN: The Senate of the United States has under consideration legislation which would stimulate the development of processes by which the potable water supply in the United States might be augmented by the extraction of fresh water from sea and other saline water.

A Member of the Senate, Senator Case, had noted in a popular magazine a few lines indicating that some "Swedish scientist" had developed a process whereby such extraction could be accomplished at a very low cost. Checking further it

LONG BEACH CALIF. OCT 25 1949

was found that the magazine had lifted the article from the Journal of Commerce I corresponded with the writer in London who had sent the story to the United States. He has been good enough to give me your name and address.

The Congress would be deeply grateful for any information you may be able to give us with respect to your process. If you are unable to comply with this request, will you be good enough to write in order that we know that you have received this communication?

Full public hearings were held regarding a number of the processes. The testimony will be published within a very short while. I shall be only too glad to see that you receive the publication when it becomes available.

Sincerely yours,

MILLS ASTIN, *Chief Clerk.*

BALTZAR VON PLATENS LABORATORIUM,
Stockholm, May 15, 1951.

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
United States Senate, Washington, D. C.:

In answer to your letter dated April 30, 1951, I would like to give you the following information:

The notice, which you read about my invention, was published quite against my will, and before the invention itself was ready from a practical point of view. It was not known if a material could be found, which was able to withstand the chemical reactions, and it is still not known if there will be difficulties from calcium deposits. At present it seems as though an inexpensive material has been found, which will perform satisfactorily in construction, and it may be that the difficulties from calcium deposits have also been overcome, but it is not certain.

The experiments however are expensive—they have already cost a few hundred thousand Swedish crowns—and therefore I cannot tell you, when the invention is going to be ready.

Large machines however will be cheap to build and the efficiency is extremely high. From 1 gallon of oil one gets between 500 and 1,000 gallons potable water.

The theory of the invention is described in the United States patent No. 2520186. Also Acta Chemica Scandinaviga 4 [1950] pages 1437–1445 will be of interest. Since the time, when the patent application was made, there have been several important practical developments. (The reprint is carried in the appendix.)

Only as a reference, I would like to mention that I am one of the two inventors of the Electrolux refrigerator—the silent refrigerator or the flame that freezes. Further I beg to refer to the Nobel prize winner, Prof. P. W. Bridgman at the Harvard University.

Yours very truly,

BALTZAR V. PLATEN.

Senator ANDERSON. We have a statement from M. B. Somerfield, director of the Mayence Research Associates. This research laboratory in Longwood, Fla., the Mayence Research Associates, seems to be quite hostile to the suggestion of rain making, but I think we should incorporate it in full in the record.

(The statement from Mayence Research Associates is as follows:)

MAYENCE RESEARCH ASSOCIATES,
Longwood, Fla., March 12, 1951.

Hon. GEORGE A. SMATHERS,
Senate Office Building, Washington, D. C.

MY DEAR SENATOR: Enclosed is a statement, with a copy for your own files, that I would like to have you present for me before the Joint Weather Control Committee, of which you are a member. This statement is in opposition to any appropriations for rain making in any of its forms based entirely upon evidence that no one has ever yet been able to make rain.

It has been my intention to appear personally before the committee, but for some unexplained reason the three bills covering this subject were delivered in today's mail. The statement has, of course, been rushed and my lawyers have not seen it. So, I hope there is no libel in it. It is impossible for me to get to Washington on such short notice and without even knowing which of the 3 days this week I would be called.

May I, therefore, impose upon you to read my statement so that it will be considered in an effort to save the taxpayers a few of those dollars we all need for more worthy purposes?

Thanking you, I am,

Very truly yours,

M. B. SOMERFIELD, *Director.*

STATEMENT PRESENTED SENATE COMMITTEES AT HEARINGS COVERING BILLS ON THE SUBJECT OF JOINT WEATHER CONTROL

This statement is in opposition to the passage of any and all bills before the Senate of the United States, as they pertain to the subjects of weather modification and control or the artificial production of precipitation, because no one has, as yet, produced artificial weather modification or artificial production of precipitation. Here are the facts:

On July 12, 1946, Vincent Schaefer produced artificial snow under controlled laboratory conditions at the General Electric Co., at Schenectady. From further research it was learned that dry ice and silver iodide crystals would each precipitate supercooled moisture, again under controlled laboratory conditions, and from this it was deduced that rain or snow could be made by seeding supercooled clouds.

In an article in Fortune magazine for February 1948, Weather Under Control, Dr. Irving Langmuir, Nobel prize winner, is quoted as having said: "I think there is a reasonable probability that in 1 or 2 years man will be able to abolish most damage effects from hurricanes." The article also contained the following: "It is quite possible that in the near future man may, if he wishes, sidetrack snowstorms outside large cities, clear winter fogs over airports, considerably reduce damage from hailstorms and droughts, and even modify the climate over large portions of the world." The article further refers to the combined efforts of the Army Signal Corps and the Office of Naval Research in forming Project Cirrus and Earl Droessler of the ONR is quoted as saying: "We're going to come up with a real science one of these days. We're going to predict weather right, and enough ahead of time to make it mean something."

Now before we go any further, let's dipose of Mr. Earl Droessler's statement because the real discovery of the science of the cause of weather was made more than 12 years ago and since I am the one who made and still holds that discovery you can understand my personal interest in these proceedings. This is not the first time that a congressional committee has been asked to appropriate funds for the purpose of discovering the causes of weather, but let us hope it will be the last time. And if making weather predictions 12 months in advance and making them correct is not far enough ahead to mean something, we can make them as many years in advance as necessary.

Now to return to the rain makers and their claims and propaganda. Most of these claims revolve around that famous day, July 21, 1949, when Project Cirrus claims credit for bringing down an estimated 320 billion gallons of rain, inferring that they caused rainstorms that spread over much of New Mexico. Here is their story, in excerpt, taken from the article entitled "They Really Make Rain," published in the Country Gentleman for July 1950:

"Shortly after sunrise, they began feeding silver iodide * * * into the cloudless sky on the wings of a 10-mile-an-hour north wind. The scientists estimated the vapor would reach the Manzano Mountains in about 2½ hours. Sure enough, at 8:30 a. m. a lone, large cumulus cloud began to form on the shoulder of the mountains, 25 miles to the south. An hour and a half later, as the torch continued to feed billions of nuclei into the air, the cloud had risen to 37,000 feet, lightning was beginning to flash and a heavy rain fell. Before the day was done, rainstorms spread over much of New Mexico. By late afternoon 1.2 inches of rain had fallen at the generator site."

Let's examine this propaganda hand-out: In the Fortune magazine article, both Schaefer and Langmuir issued the "stern admonition to seed only supercooled clouds and preferably only those extending at least 500 feet above the freezing isotherm." Then why, for 2½ hours on the morning of July 21, 1949, did Project Cirrus seed silver iodide into a cloudless sky? Since this is a process of cloud seeding and there were no clouds for hours, all claims for the process must be regarded as fraudulent. One can hardly escape the conclusion that Project Cirrus has made the phenomenal scientific discovery of the age—a rat hole in the sky down which to pour tax dollars.

The truth of that famous day is that the meteorologists on duty knew the evening before that a "front" was moving south and the chances were 9 out of 10

that sometime on the 21st there would be showers or rain, somewhere, over New Mexico. Project Cirrus intended to take full advantage of that fact to justify their cause.

It should be noted that the 1.2 inches of rain were recorded not in the Manzano Mountains 25 miles away, but at the generator site. Considering the north wind, the seeding could not possibly have had an effect where the 1.2 inches of rain fell, but only to the south, so that, if the rain makers had wanted to give a really true picture they would have set up a rain gage at the Manzano Mountains and reported what fell there. If they were not intent upon misleading those who read the reports of Project Cirrus, why should they have included the 1.2 inches of rain that fell at this generator site; rain they could not possibly take credit for making?

There is only one conclusion to make from this: Project Cirrus must have been pretty hard up for some kind of showy result to justify the methods used in reporting claims of precipitation they could not possibly have caused.

Another of the rain makers' claims concerns heavy rains accredited to some Hawaiian pineapple growers. According to the Fortune magazine article, in 1947 these people "by mistake" seeded some nonsupercooled clouds, for that's the kind they have in the tropics, and the results were so satisfactory they have continued this method. But have the rain makers told the Hawaiians they are wasting their time and money to get rains nature intended to give them anyway? Probably not, because these rain makers are still stating, according to the Country Gentleman article in 1950, that silver iodide will not produce rain from any but supercooled clouds. According to these scientific rain makers it cannot be done, but they make their claims of success anyway, and it is on this basis they come before these joint committees to ask for more money for their experiments, if one can call them that.

So now they have produced element X to bring rain from the hot clouds that silver iodide does and does not bring from cold, supercooled clouds. In the 1950 article writing about the Rogue River section in southern Oregon, the rain makers claim: "During the summer of 1949 hail ripped down on the surrounding hills as usual, but not one hailstone fell in the valley protected by element X. This could have been a freak of the weather. But it could have been a miracle."

Wonderful! Only if element X was used the cloud had to be hot, otherwise element X would not work; and if the cloud was hot then there could be no hail, for you can get hail only under cold conditions. So it was neither a miracle nor a freak of the weather. It has happened often before. The cloud was cold and hail fell on higher hills, but the warm air over the valley melted the hail on the way down. Therefore, it is evident that element X and the claims of the rain makers had absolutely nothing to do with the results. Again, I submit, their own words disprove their claims.

These rain makers claim to be able to knock the tops off clouds to check their growth before the lightning and hail stage can be reached, thus preventing terrific downpours that might cause damage, according to the Country Gentlemen article. This is now recommended by Langmuir, but in the 1948 article—I quote: "For the chain reaction to work, he explained, all that is needed is a fairly common type of cumulus cloud several thousand feet thick with a high water content, fully grown water droplets, and a vertical updraft at of least 5 miles an hour. In such a cloud, a single drop of water large enough to fall through the updraft can trigger the reaction. * * * The process spreads rapidly through the cloud until all the water is gathered into drops too heavy to stay aloft, and the aerosol collapses." As I understand this, practically every single drop of water could be wrung from the cloud. And, since it is a matter of record (in the U. S. Weather Bureau's Monthly Weather Review, for January 1950, p. 4) that a high-water-content cloud can drop from 10 to 12 inches of rain, within an hour's time, and still retain some moisture aloft, the results could be just the opposite from that desired—and claimed—a cloudburst and a disaster. According to their own theories, by knocking the tops off clouds you should knock the bottoms out, too. If they cannot obtain the results they claim, then artificial rain-making stunts are failures.

According to the record, when Canada tried rain making, out of 57 tests they got precipitation but 20 times, once as much as one-quarter of an inch. Is that success or failure? Is that meeting the claims for modifying the climate or reducing a drought?

If the rain makers can clear winter fogs over airports, why should the Government spend many millions to install electronic devices for blind landings during fogs and storms?

Fantastic figures of probabilities are cited to prove their points, but it was this kind of mathematics which proved conclusively that the East could not have two consecutive warm winters when, in fact, the second winter recorded new high-record temperatures for the winter season.

The great test was New York City, and, just imagine it, the rain maker could take no credit for producing any artificial rain because the heaviest downpours occurred just when and where nature aimed them, with no interference from the stunters. If you will study the record, you will note that many days, when the clouds were not seeded, the most rain fell, and on some days when seeding was done, there was no rain where the rain makers wanted it to fall. In fact, "the department of water supply, gas, and electricity disclosed rather sheepishly yesterday that a generator crew was out in the midst of Saturday's storm trying to make rain." This was the heaviest downpour of the season. Is it any wonder the rain maker's contract was not renewed? Is it not proof that his claims were without practical foundation?

Dr. Irving Langmuir appeared before a press conference in New York City, January 25, 1950, where he discussed the rain-making problem for New York City, and Reporter Richard K. Winslow, of the New York Herald Tribune, quotes him as saying that a single day's seeding triggered enough rain, in New Mexico, to fill to overflowing all of the New York City's reservoirs, starting empty. But less than 9 months later, this same Dr. Irving Langmuir, speaking at Schenectady, N. Y., before the closing session of the National Academy of Science, is reported by Reporter Earl Ubell, of the New York Herald Tribune, to have announced that seeding clouds in California, Arizona, and New Mexico last winter and spring "may have produced a drought in those areas while creating abundant rain 2,000 miles away * * *." Now, according to Dr. Langmuir, in July 1949 cloud seeding in New Mexico produced more than an inch of rain, and with an inference that up to 5 inches was produced, but a few months later, the same cloud seeding in the same State produced a drought. This, in itself, is an admission that these rain makers not only have never made rain, but they have no idea what could make rain, for, according to them, they have produced, by the same method, both rain and its opposite in nature, a drought, without any control or expectancy for the results of their actions.

According to the identified facts presented in this statement, it is obvious that no one has ever yet made rain and there is no prospect of making rain, any rain at all, by the processes presented before this Joint Weather Control Committee. Therefore, there is no need to appropriate any funds or set up any additional salaries until such time as proof can be submitted that those appropriations can be put to satisfactory use. There is no need to appropriate funds for the purpose of trying to discover the physical processes, in other words, the scientific causes, that produce weather because this has been a matter of record for many years and that can be adequately proved beyond any doubt or question.

I am, therefore, opposed to the passage, at this time, of any or all of the bills before this committee as they pertain to the subjects of weather modification and control or the artificial production of precipitation.

M. B. SOMERFIELD,
Director, Mayence Research Associates, Longwood, Fla.

Senator ANDERSON. Dr. Emil J. Rausch has submitted a statement for the record:

LOS ANGELES, CALIF., *March 17, 1951.*

Re: Committee on Interior and Insular Affairs, Senator O'Mahoney, S. 1300
Mr. MILLS ASTIN,
Chief Clerk,
Senate Office Building, Washington, D. C.

DEAR SIR: This will acknowledge the receipt of your note dated February 28 together with the copy of a press release of February 27 headlined "Joint weather control hearings scheduled by Senate committees," which says a testimony regarding the extraction of fresh water from sea water is to continue on March 19.

My intense 2-decades-old interest in the problem of reclaiming fresh water from saline waters would have induced me to assume the traveling expenses involved, in order to appear at said hearings, were it not for a most discouraging disappointment I had 2 years ago, in connection with this very project.

From Senator O'Mahoney's letter of April 5, 1949, and from the wording of his bill, S. 1300, I understood the Committee on Interior and Insular Affairs will consider only the feasibility of the over-all project, not individual methods of

conversion, and, further, that the Secretary of the Interior is to be authorized to conduct the necessary research.

Thus, I addressed a detailed report on my proposition to Mr. Julius A. Krug, then Secretary of the Interior, offering my professional services free of charge, so that the results from my own extensive research work on saline water conversion may be preserved and utilized to the advantge of the entire Nation.

No response whatsoever, not even a simple acknowledgment of my offer, was forthcoming, though, certainly, an uncivil attitude against a man with a scientific background of more than 40 years, which is hard to understand, no matter what Mr. J. A. Krug's personal opinion of my proposition may have been.

At any rate, that experience cautions me against any further approaches which are not expressly proposed by the Department of the Interior, and, at this time, I prefer to restrict myself to a brief statement attached to this, which, in accordance with your suggestion, may be filed for the record. Thanking you in anticipation of your good will, I am,

Very truly yours,

EMIL J. RAUSCH.

A STATEMENT SUBMITTED FOR THE RECORDS OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS, CONCERNING PRACTICAL MEANS OF PRODUCING, FROM SEA OR OTHER SALINE WATERS, WATER SUITABLE FOR BENEFICIAL CONSUMPTIVE USE, PARTICULARLY REFERRING TO BILL S. 1300 INTRODUCED BY SENATOR JOSEPH C. O'MAHONEY, ON MARCH 18, 1949

From 1929 till 1945, while professionally associated with the mining industry of southwestern Arizona, and while serving with the Arizona State Department of Health, at the university in Tucson, I was duty-bound to travel regularly over the most arid parts of the United States and Mexico, such as the region south of Ajo, Ariz., via the border station Sonoyta to Puerto Penasco and the Bahia de Adair, around the head of the Gulf of California, to El Golfo and Puerto Isabel, at the mouth of the Colorado River, and back to the States via the border station San Luis, to Yuma, Ariz.

The continual sight of all that desolate land, an area of approximately 30,000 square miles, has challenged my ambition to find a feasible way of reclaiming fresh water from the adjacent sea, through harnessing the energies of Nature itself.

Of course, many attempts of that kind have been made in the past, for instance, distillation by focusing solar radiation upon stills of various designs. But experience has shown that such devices are not fit for producing quantities of fresh water anywhere nearly sufficient for agricultural, industrial, and domestic purposes.

Thus, I have taken advantage of certain achievements of modern science and during those many years of my professional activities in the desert, I have developed a technique of converting sea water into fresh water the proper employment of which makes it possible to provide for an inexhaustible supply of perfectly pure water, from the ocean, at a cost price of less than $20 per acre-foot, i. e. about 300,000 gallons.

As far as I know, $20 per acre-foot would be about one-fourth of the cost up to now authenticated for any other sea-water-conversion process, which has been publicly submitted for trial. However, in order to avoid any statement which could be construed as misleading, I must admit that my $20-per-acre-foot figure has been based upon the wage and price levels of 1949, that is the time when I have approached Senator O'Mahoney at the first time, with my letter of March 21, 1949.

With those wage and price levels of 1949 in mind, I may say, here in southern California, returns of $18 per acre-foot would have sufficed to cover the salaries of the staff and the cost of operating and maintaining a processing plant, provided that it is located next to the seashore, and that it is fully automatically controlled.

At that time, the erection of a pilot plant big enough to verify my figures would have required an investment of approximately $100,000, as there is no special but only standard equipment necessary, with my technique.

The capital investments required for the erection of large-scale production plants, however, would be quite considerable, in any case, and would have to be made out of public funds, probably in form of governmental subsidies, and those large-scale production plants would have to be operated as a publicly owned utility, that is, on a nonprofit basis, in a manner like, for instance, the water and power works of the city of Los Angeles.

Recognizing the fact that only the Government would be in a position to finance those enormous establishments required for large-scale reclamation of

fresh water from the sea, I did not consider it necessary—or even advisable, because of the international tension—to apply for patent rights, as it would be my privilege to serve as a consultant any way the Government may wish me to serve.

In case there would result, from this preliminary statement, a real interest in my proposition, on the part of any legislative or administrative authority, I would gladly submit exact data for the evaluation of my technique, with the understanding, however, that my priority rights, if any, are officially protected. My credentials and reference sheets covering 40 years of my professional life are offered for inspection.

Respectfully,

EMIL J. RAUSCH.

Senator ANDERSON. The J. G. White Engineering Corp. had previously sent a letter to Senator O'Mahoney relating, I guess primarily, to extraction of salt water, and that will be incorporated in the record.

(The letter above referred to is as follows:)

THE J. G. WHITE ENGINEERING CORP.,
New York, March 6, 1951.

Mr. MILLS ASTIN,
Chief Clerk, Senate Office Building,
Washington 25, D. C.

DEAR SIR: This will acknowledge receipt of your letter of February 28, 1951, enclosing a press release dated February 27, 1951, captioned: "Joint weather control hearings scheduled by Senate committees."

We thank you for the invitation to appear at these hearings, but the press of other matters may prevent our sending a representative to Washington to attend.

Under date of June 30, 1950 we addressed a letter to the Honorable Joseph C. O'Mahoney, chairman of the Committee of Interior and Insular Affairs of the United States Senate. A copy of this letter is attached, which you may wish to file for the record.

We trust this statement may serve the committee's purpose and that they will feel free to call on us for any assistance within our capabilities.

Yours respectfully,

THE J. G. WHITE ENGINEERING CORP.,
By E. N. CHILSON, *Vice President*

THE J. G. WHITE ENGINEERING CORP.,
June 30, 1950

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee of the Interior and Insular Affairs,
United States Senate, Washington, D. C.

HONORABLE SIR: This is in reference to S. 1300 which you introduced during the first session of the Eighty-first Congress.

We would like to make known to you and the members of your committee our interest in the pending legislation, and for this reason we cite two examples from our own experience in the production of fresh water from sea water, and examples from the observations by our engineers in various parts of the world of typical foreign areas where fresh water is in short supply.

We offer this information, thinking it may assist you in demonstrating some of the practical benefits which may be expected from the research program if S. 1300 is enacted and more economical methods are developed.

EXAMPLES OF THE J. G. WHITE ENGINEERING CORP. EXPERIENCE

Both of the plants referred to in the following discussion produce water of acceptable quality but the cost of production is far too great in instances where water is to be used for irrigation or for domestic supply except in cases where fresh water cannot be obtained by any other means.

1. *Aruba, D. W. I.*—In 1943, the J. G. White Engineering Corp. completed the design of one of the largest evaporators ever installed, consisting of a quadruple effect, steam evaporator for the Lago Oil & Transport Co., Ltd., subsidiary of Standard Oil Co. of New Jersey, for use at their refinery in Aruba, Dutch West Indies. The designed capacity was for producing 6,000 barrels of 42 gallons each, equaling 252,000 gallons daily. This evaporator lay-out is presently producing, with no enlargement of the original facilities, 11,000 barrels daily, equaling 462,000 gallons.

Sea water is evaporated in a series of effects (evaporators) in which the pressure and temperatures are progressively reduced under design conditions from about three atmospheres (273° F.) to about one-seventh of an atmosphere (125.4° F.).

The Aruba plant does not lend itself to the development of a significant estimated operating cost since it includes features to serve the steam plant with which it is associated.

2. *Las Piedras, Venezuela.*—At the Amuay refinery of the Creole Petroleum Corp., Las Piedras, Venezuela, during the early part of 1949, we designed and installed a plant somewhat similar to that installed at Aruba, with a designed capacity of 200,000 gallons per day. In this plant there is a series of four evaporators in which the pressure and temperatures are progressively reduced from about one atmosphere (215° F.) to about one-seventh of an atmosphere (130° F.).

Before deciding on this type of plant for Amuay, we examined into a multiple unit vapor compression distillation type developed under the Badger Kelinschmidt patents, but abandoned this idea because of the relatively great initial cost and as at that time no suitable compressor of the size and efficiency required had been developed sufficiently to assure successful operation. Each unit of the vapor compression distillation type of plant has a single evaporator, the vapor being compressed and used as a source of heat for evaporating sea water. The principle employed is that of a heat pump and, when the practical and economic aspects have been solved for sizable plants, this type of plant promises to effect fuel efficiencies as high as four to five times that of the plant which was selected. The use of a Diesel engine drive for the compressor offers greater opportunity for fuel economy than the electric motor drive which was contemplated because of conditions peculiar to this particular installation.

The Amuay plant represents an installed cost of about $1.80 per gallon per day of capacity. Its estimated operating cost is $1.33 per thousand gallons of fresh water produced. This includes the cost of fuel oil at 5 cents per gallon; auxiliary electric power at 1 cent per kilowatt-hour, direct labor, supplies and maintenance materials, but does not include any fixed charges or any of the charges of the steam-generating plant other than the cost of fuel oil. About 70 percent of the estimated operating cost is the cost of the fuel oil consumed.

EXAMPLES OF FOREIGN AREAS

From observations by our engineers in various parts of the world we offer the following two typical examples of foreign areas where fresh water is in short supply, which could materially benefit from the development of practical low cost know-how for producing fresh water from sea water.

1. *Athens, Greece.*—Athens, with a population of about 1,000,000, is a good example of a city that would be greatly benefited by an economical method of developing a potable supply of water from the sea, which is only 5 miles distant. It is now partially supplied from a reservoir built on a mountain stream which is only 18 miles from the city but the rapid increase of population now makes it necessary to go over 100 miles to the springs at the foot of Mount Parnassus for additional water at a cost of more than $20,000,000, a tremendous sum for an impoverished country.

2. *Africa, Red Sea area.*—The desert bordering the Red Sea in Africa would no longer be a barren inferno if irrigation waters could be extracted from the sea at a reasonable cost. There is little doubt that the addition of fresh water to these desert sands would make this area highly productive.

The foregoing information covers briefly our experience in turning salt water into fresh water and some of our observations on the desirability of a much more economical means than exists at the present time.

We trust that this rather meager information may be of some help and we hope that you will feel free to call upon us if you think that we can be of any further assistance.

Respectfully submitted.

THE J. G. WHITE ENGINEERING CORP.,
E. N. CHILSON, *Vice President.*

Senator ANDERSON. We have heard from Paul C. Mulligan, of Seattle, Wash.

SEATTLE, WASH., *March 22, 1951.*

Mr. MILLS ASTIN,
Chief Clerk, Senate Office Building, Washington, D. C.

DEAR SIR: This will acknowledge your good letter of February 28, 1951, relative to water-extraction processes and subjects now under discussion by subcommittees charged with handling the problems.

My appearance before your committee hearings would involve certain time and expense which could have no advantage, as a written summary of the material and proposals submitted would have to be provided to permit consideration and action.

If you care to enter the following information in your records, the statements enumerated below are respectfully submitted.

1. These processes and proposals are submitted by an expert mechanical and marine engineer with many years of practical experience at sea and on shore, in the operation, design, construction, and tests of a number of improvements in simplified and efficient salt-water evaporation and distillation systems and equipment.

2. Use of the simplest and most efficient of the several processes and systems developed and tested, will permit any community to produce its own supply of pure fresh water, independent of any bomb-destroyed or contaminated reservoirs or supply systems. (Navy ships anchored in the Hudson River supplied a limited amount of pure water to New York City during the recent emergency. Another emergency in Ketchikan, Alaska, and in Columbia, Pa., where frozen supply conditions made the population helpless, are mild samples of the importance of this water-supply problem.) But your committee members probably know all about that, as well as the world shortage of pure water which has been developing, the salting up of deep wells near the coast of southern California (and expected in Long Island, N. Y.), all of which requires action which permits less than the usual delays.

3. There should be no prolonged delays in acting on the following proposal, by which you have everything to gain and nothing to lose. A fund of about $100,000 to be provided for payment for the most acceptable process and equipment submitted by anyone, for production of pure, fresh water from salt sea water and/or contaminated river or other water.

This will cause a lot of your staff of high-paid engineers to stretch themselves on the problem and possibly deliver something of much greater value than its cost, because their success will result in immediate and potential value to the country and to the world.

A definite reward of the above nature will result in the contribution of many times the award by private capital, out of which will come the results of a tremendous amount of ingenuity and brainpower that could not otherwise be so concentrated.

4. When you have something of definite character and purpose to offer to any engineer or inventor, you can inform me and I will arrange to disclose and to demonstrate one or more of the processes I have developed.

I will consider it a privilege to compete with any other process you may have to consider, but a definite acknowledgment of rights and the source of information should be delivered before any demonstration or tests are made for your engineers and experts.

5. I sincerely commend for your consideration the article authored by Mr. Oscar L. Chapman, Secretary of the Interior, and published in the February 1950 issue of the American magazine. In this short article he has given the most far-reaching, comprehensive, complete, and intelligent analysis and appraisal of water conditions throughout the Nation, showing how it can affect war operations, as well as controlling the imperative and increasing domestic, agricultural and industrial progress and future activity of every district which requires more than the rain barrel and cistern water supply system which they all started with. The author should be given a prominent seat in the hall of fame.

He does not know that I have been extracting crude oil from his Colorado oil shales, from samples he authorized shipped to me by his able assistant Bureau of Mines Chief, Mr. Catlett. I have not disclosed to his chief Mr. Guthrie, at Rifle, Colo., just how I do the extracting, but I am taking out the oil (with a byproduct of $15 per ton in copper from the residue) and still, I am personally financing all developments and tests. I can quickly abandon all future tests and efforts, as soon as it can be known that such efforts are desultory. That is up to your determination. You can make it produce, and accelerate it, or you can delay it. That is your province and privilege.

I desire to inform you and the committee, to which this may be submitted, that I am not looking for any job of any kind; that I am a lone operator, strictly on my own and not under control of any company or other control than my own personal limitations.

I will take the rare privilege of referring you to Vice Adm. William A. Glassford, Monticello, Calif., or to Rear Adm. Harold E. Bowen, Navy Department, Washington, D. C. Many years have intervened between our last thoughts and contacts, and they may not believe that I am still active and operating as an engineer.

In any research or development effort, I am able to command the assistance of several exceptionally competent designing and operating engineers, but such men are receiving top pay in their present positions, and it is logical that I cannot divert their activities when I am unable to adequately finance my own.

Your consideration of the purposes and wholesome objectives of the above proposals, is respectfully requested.

Yours truly,

PAUL C. MULLIGAN.

P. S.—I request the privilege of forwarding copies of this letter to New York City, the Secretary of the Navy, and to the State of California.

Senator ANDERSON. Benjamin A. Moeller has a statement to be filed for the record. He is dealing with a basic patent on the extraction of salt water.

(The statement of Mr. Moeller is as follows:)

BLACK MOUNTAIN, N. C., *March 8, 1951.*

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
Senate Office Building, Washington, D. C.

MY DEAR MR. ASTIN: Thanks for your memorandum of February 28, 1951, apprising me of my opportunity to appear at the hearings to be held later this month on S. 5, which it is presumed is practically a verbatim copy of S. 1300 of the Eighty-first Congress (if not, I would be pleased to obtain a copy of S. 5 at your earliest convenience).

Neither my own interests nor those of the Government, it is believed, can be better served by my personal appearance than they can be by the submission of a written statement of my views, which, accordingly, is herewith enclosed.

It is requested that it be filed for the record with my letter of April 26, 1949, and its enclosure.

Yours very truly,

BENJAMIN A. MOELLER.

SUGGESTIONS CONCERNING THE ENACTMENT OF LEGISLATION AUTHORIZING APPROPRIATION OF FUNDS FOR THE DESALTING OF SEA WATER

The bill (S. 1300, 81st Cong., no copy of S. 5, 82d Cong., on hand), page 4, lines 8–15, provides that all patents acquired by the Bureau of Reclamation under it shall automatically become available for use by the public in general. It is suggested that exception be made in the cases of joint patents when the written consent of all the owners of a joint patent and their entire respective interests therein have not been obtained or acquired by the Bureau of Reclamation; that in such a case use without the written consent of all the owners of a joint patent be restricted by law to the joint owners thereof and the Bureau of Reclamation; and that the Secretary of the Interior, acting through the Bureau, be authorized, if the Bureau becomes a joint owner, in order to simplify title through integration, to assign or cause to be assigned to one who is both a joint inventor and a joint owner of such invention such joint patent rights in it as may be acquired by the Bureau of Reclamation, in partial consideration of royalty-free use, by the Bureau, of the invention covered by the integrated patent rights for the purposes enumerated in this act.

The purpose of these suggestions is to safeguard my interests in my basic invention (which cannot be patented before a model is in successful operation) without defeating the main purpose of the act. Because it is believed this invention will be found capable of developing energy from compression distillation and for the extraction of the mineral and the chemical byproducts of the distillation with unmatchable economy I anticipate the execution of an agreement with the Bureau of Reclamation concerning its use (even though I retain ownership of my patent rights). In order to avoid jeopardizing of my ownership interests with probably disastrous results through a mere legal technicality that might otherwise

arise from such agreement, I suggest these amendments. Unless your bill is modified or amended others might, because of the opportunity afforded through either their direct or their indirect employment by the Government, add a more or less desirable or even essential improvement requiring comparatively little inventive ability but of such a nature as to entitle them to become recognized by the Patent Office as joint inventors with me and, as the law now stands, consequently, without my knowledge or consent, to grant licenses to third parties to use my invention in consideration of only nominal royalties or even no compensation whatsoever. Also, should the Government become the owner of a joint interest in my invention, my share could automatically under the bill as worded become available for free use by the general public without one cent of compensation to me.

Because of the enormous amount of work done by me to originate this invention, because of the extraordinary character of the creative imagination demanded, and because of the singular perseverance necessitated by the prodigiousness of the undertaking over a period of considerably more than half a century under most discouraging conditions (the general skepticism of scientific authorities), and in view of the fact that the product of my inventive efforts did not arise from any prior contractual relationship with the Government, either directly or indirectly, I feel that any agreement which makes no provision for securing to me my paramount moral right to the benefits my efforts and my accomplishments entitle me would be a travesty of justice.

BENJAMIN A. MOELLER.

BLACK MOUNTAIN, N. C., *April 26, 1949.*

Hon. JOSEPH C. O'MAHONEY,
United States Senate, Washington, D. C.

MY DEAR SENATOR: The passage of your bill "aimed at developing large-scale methods of taking the salt out of sea water" for "public, industrial, and irrigation uses" of the purified water together with the appropriation of the necessary funds for construction and operation of test plants is awaited with eagerness.

Should this proposed legislation unhappily not be given a sufficiently hospitable reception by the Congress and should you then believe that the probability of passage would be greatly increased if this body, of which you are a distinguished Member, were assured that there is at least one method promising most economical and abundantly adequate means for removing salt from cubic mile upon cubic mile of sea water indefinitely and pumping the pure water to any point where needed (rather than being left with the impression that the Department of the Interior will be expected to test a multiplicity of methods, probably none of which has as yet been considered sufficiently economical on such a stupendous scale and for such purposes), then let me suggest that I am ready to offer a method which is ideally adapted to the handling of this supercolossal project. It has been proved sound mathematically, scientifically, and technologically. None can match it in promised economy and efficiency. All that remains to prove its worth in practice is the construction and testing of the means for its implementation.

The method referred to involves the artificial evaporation and condensation of the water by compression distillation with mechanical (nonelectric) energy. It would furnish compression energy for evaporation at considerably less than $4 per acre-foot. The cooling effect for condensation would be practically free, since it is obtained from incoming water. Through a heat-exchange system the heat developed would be used over and over again. It could also produce enough mechanical energy to pump the water up 10,000 feet (if necessary) and deliver it 1,200 miles inland at a cost for energy of $1 per acre-foot. If this method is used the cost of irrigating any amount of land in the West and Southwest could be totally self-liquidating through exploitation of the magnesium, bromine, uranium, and other metallic and chemical contents of the residue. This concentrate would, of course, if marketable in this form, be sold to private concerns for the extraction of chemicals and metals. Magnesium, for example, could then be produced more cheaply per pound than steel is now being manufactured. There would even be a handsome profit, which the Government could apply at first toward expansion of the system and, later, toward liquidation of the national debt. It is not inconceivable that over a period of a century or two the debt could be wiped out in this manner. Tens of thousands of power plants, each far simpler, more compact, and much less expensive than steam plants and producing from fifty to hundreds of thousands of horsepower of dependable energy could be

built wherever needed. There would be no need to worry about fuel with which to operate them, no matter where located, for the heat is provided free by nature at the plants themselves.

The only energy that could have such wonderful possibilities is secondary atomic energy—that shot out from the sun instead of from terrestrial fissionable material. It is safe, clean, absolutely free, inexhaustible, overwhelmingly adequate in amount everywhere regardless of weather, calm, season, or darkness. Ordinarily referred to as atmospheric heat it has several remarkable characteristics.

1. By means of the reuse at least 15 times of the heat in the atmospheric envelope of the earth, nature enables us with astonishing convenience to turn the subjacent seas into fresh water as needed far more efficiently than even she herself performs this miracle in giving us rain.

2. The evaporation and the condensation both are effected without the use of a substantial amount of relatively expensive electric energy, but at the same time when electricity is needed, as it is in the electrolytic process of extracting magnesium, it can be produced far more inexpensively than from any other source. The cold for condensation is obtained simply and directly from the water being and about to be evaporated.

3. All energy phases of the process of making water available for use, from lifting it in its salty state out of the ocean to its delivery purified within any interior State, are covered by my method. In addition, this method offers all the energy needed for adapting the valuable byproducts for use. That is why expenditures for plants and systems incorporating it will be more than self-liquidating over a period of years. Electric energy produced by it will cost considerably less than 1 mill per kilowatt-hour. (Note: Grand Coulee sells energy to industries at 2 mills per kilowatt; TVA at 3.25 mills. Many utility companies charge a rate of 10 mills or more. Primary atomic energy promises no substantial savings as yet.) It would, in view of all the above, be gross and profligate waste for us not to avail ourselves of free atmospheric heat energy or, at least, investigate its possibilities.

But there is one fly in the ointment. It is, however, easily plucked out and disposed of, provided everyone is open-minded. Many physicists and engineers have been indoctrinated with the idea that nature will not permit the development and exploitation of this energy. They will tell you a principle known as the second law of thermodynamics prevents its release economically. But just as a great many alleged impossibilities have been accomplished in the past so will this "impossibility" also be achieved. Let those who deny the availability of atmospheric thermal energy (1) state how much original research they themselves have done in this field and (2) produce all the evidence they can obtain from any source in support of their contention. Let this negative evidence be compared by unbiased experts with both the pure and the applied thermodynamic science constituting the positive or affirmative evidence which I have developed through 53 years of original research plus the discoveries made by others. Let these experts weigh the evidence pro and con. The inevitable result will be a decision for the affirmative. The parroting of a defeatist cliche is due to mistaking a technological difficulty (now completely overcome, at least in theory) for a scientific impossibility. Any judge knows that the negative testimony of a million witnesses who have not been in a position to see an occurrence (in this case because of lack of sufficient original research) should be greatly outweighed by the positive testimony of a single reputable witness regarding it who has seen it (in his mind's eye) and can give a detailed account of it verifiable by others. Yet, in scientific circles the decision is sometimes given to those producing only hearsay evidence which in turn is based on nothing more than other hearsay evidence, because there are so many reputable witnesses producing it and they seem, because of being able to qualify as expert witnesses in this general field, to be worthy of full credence in a special area of this general field in which their knowledge is not outstanding.

Witness, for example, the error, carried along about 2,000 years without question as to its truth, that when not retarded a heavy object always falls faster than a light one. Because this doctrine was based on the teachings of Aristotle, one of the very greatest scientists and philosophers of the ancient world, the error was perpetuated until Galileo, then comparatively an unknown, proved that the acceleration of gravity was the same for all bodies, whether large or small, whether lead or lint. He had dared to doubt and was the first of all the authorities during two millenniums to subject the question to original research.

In respect to the current doctrine relative to the exploitability of atmospheric heat, if prestige of scientific position buttressed by erroneous hearsay testimony

is allowed to prevail over the discoveries made by me during a half-century of original research we deliberately reject the lessons that Galileo tried to teach us. They were: (1) Use common sense, but let it not obstruct direct research or be a substitute for it. (2) Respect scientific prestige, but fail not to demand proof and examine the evidence critically. (3) Observe closely, but be not deceived by appearances.

Aristotle was satisfied that the heavier a body the faster it falls. His common sense told him so. The idea that velocity of fall is independent of weight would be illogical. Why examine critically the self-evident?

His great prestige in the field of natural philosophy dispelled all doubt of the correctness of his teachings during a period of 20 centuries. Why doubt a pre-eminent authority, especially when common sense corroborates him. Surely, they cannot both be wrong. Besides, don't we actually see rocks fall rapidly while leaves float downward gently? Galileo is mad when he expects us to believe that neither common sense, nor the highest authority, nor our own eyes can be trusted in such an elementary scientific matter. Yet any student of physics knows that the authorities were triply deceived and that Galileo entirely sane, proved to an unbelieving world that nothing less than direct and thorough research gives adequate support to scientific pronouncements. History is replete with similar deceptions.

Man had from the very earliest days seen the sun, moon, and other heavenly bodies encircle as satellites a flat and fixed earth. All the evidence pointed to the fact the universe is geocentric. Ptolemy, the celebrated astronomer and geographer (circa A. D. 140–160), affirmed this self-evident concept. Besides, nothing else made sense until Copernicus 14 centuries later engaged in thorough-going research which proved again the folly of trusting in science based on nothing more than common sense, prestige, and casual observation.

Lest it be thought that men of antiquity alone could be misled and that moderns are open-minded there is the case of Westinghouse who proposed to stop trains with air. Could anything be more absurd? Commodore Vanderbilt thought not and promptly rejected the air brake.

A common expression up to about two generations ago was "I would no more think of doing that than I would of flying," implying that flying was manifestly impossible. Everyone with common sense knew that free, controlled, and sustained flight in a power-driven, heavier-than-air machine would never, because of the very nature of things, become possible—everyone but Langley, the Wright Brothers, and a few other misguided simpletons with creative imagination fostered by a rare attribute known as an open mind.

It has always been infinitely easier to offer evidence that an exceptionally difficult task is impossible of accomplishment than to prove that it can be done; to dismiss "impossibilities" than to perform miracles.

The question these and all similar cases pose is this: When the matter at issue is of transcendant importance to the welfare of the human race, such as the use of atmospheric heat for power purposes, how is one to distract scientific authorities from their death grip on preconceived ideas, from their desperate desire for orthodoxy, long enough to examine proof of the weakness of their negative views and the soundness of opposing ideas if they persist in asserting the impregnability of their position because of the dictates of common sense, the opinion of all the authorities, the evidence of statistics, etc., and refuse to be disturbed.

Fortunately, there are top-flight authorities who admit that some generally accepted basic scientific ideas may bear reexamination. Among them is Dr. Enrico Fermi, renowned Nobel Prize nuclear physicist of the Argonne National Laboratory, University of Chicago, and author of a textbook on thermodynamics. After studying my paper containing a discussion of the second law of thermodynamics and propositions supporting my claim that atmospheric heat can be made available for power purposes he told me he would not deny the feasibility of exploiting it economically. This paper contains most of the newly discovered abstract science in the premises forming the proof. A copy is enclosed herewith for examination by physicists thoroughly familiar with thermodynamics and the kinetic theory of gases and who are deeply interested in providing water for the arid regions of the West and Southwest especially.

Further proof of the availability of atmospheric thermal energy is developed in my 50-page treatise covering its practical application and describing the design and operation of a basically new prime mover invented by me which untilizes it. This paper has been examined by Charles W. Brabbee, doctor of science in engineering, University of Vienna, founder of the Research Institute of the Royal Technical Institute of Berlin prior to World War I. In his unsolicited

brief on it he states among other things: "The general idea of your machine is not only plausible but actually used by nature to develop the gigantic power we experience with hurricanes." (Note: Dr. Brabbee, now an American citizen, was at one time the only professor of air conditioning in all Europe, and is recognized in the United States as one of the pioneers in this science. He is the author of the chapter on Heating, Ventilating and Air Conditioning in Hütte, the European Kent. Kent is the leading mechanical engineers' manual in the United States. Dr. Brabbee is mentioned in this publication.) He sees no conflict between the operation of my projected engine and the second law of thermodynamics.

If you want an estimate of my personal qualities I refer you to W. R. Woolrich, dean of engineering, University of Texas, Austin. Dean Woolrich was during World War II president of the Engineering Colleges' Research Association embracing more than 70 technological institutions of learning which rendered services to our Government.

There are many problems to be solved in order to render sea water suitable for irrigation, industrial, and general public purposes. They are mainly technical, economic, and practical. It is not enough that the objectionable matter be removed, leaving the water pure but it [the water] must also be delivered at points of consumption at a cost low enough to encourage its liberal use. By what method can that be done? It is difficult to conceive of a more effective way to keep its delivered rates low than to exploit the byproducts of the separation. Otherwise, if the water is to be conducted hundreds of miles inland, the cost might prove prohibitive. It must, therefore, also be possible to extract the marketable byproducts from the residue economically and at a substantial profit. It is believed that the integration and meeting of all these requirements can best be effected with released and applied atmospheric heat energy. No other agency can approach it in economy for the multiple purposes indicated. There is probably none other that can do the job at all either alone or in combination with others except at unavoidably prohibitive costs. If so, the sooner that fact is ascertained the better, because the more definite our information the more effectively we can act. For if all the States needing water obtainable in no other way are to be satisfied it is truly a superstupendous project and Lilliputian instruments, no matter how numerous, are illy adapted to the purposes. It would, therefore, be decidedly imprudent to pass up without investigation any proposed method promising the necessary capacity and economy.

If diligent efforts are made prior to congressional adjournment to take the necessary steps to develop this project (in which event this opportunity may be extended for an additional period) I shall ask no consideration (royalties) for the use of my invention by the Government in the sweetening of sea water and the supplying of fresh water to the points in any State where it is to be used other than that the Government cover the cost of building a successful experimental model of my prime mover and the direct and indirect expenses that must be incurred to give it commercial value and to enable me to vouchsafe to the Government the right of free use of my invention for the purposes suggested. It is to be understood that such assistance on the part of the Government does not in any manner entitle it to an assignment of patent rights, but merely use, free from payment of other compensation, for strictly governmental purposes. Given this free use for enumerated purposes assignment would be superfluous. Incidentally, it is my intention, when and if patent rights are secured on an operable prime mover, to license manufacturing rights to numerous concerns who have the public interests continuously in mind and particularly those of the consumer. Thus everyone will be benefited alike.

Provided it does not endanger private incentive, initiative, enterprise, or self-reliance yardstick industry may, within limitations, be considered a proper instrumentality of Government for regulatory purposes.

Since the Commissioner of Patents will not issue any letters patent until the engine is in successful operation, care must be taken that a public disclosure of its design and mode of operation be not made, since I might in such event lose all exclusive rights to its manufacture, sale, and use. This would also probably mean the loss to the Government of this splendid opportunity. Incidentally, I am eager to cooperate with the Government in every way practicable to make your project a success without weakening our free-enterprise system or individual self-reliance.

Unnecessary publication of facts which might encourage antidemocratic interests to seek further data on this project should also be avoided in the interests of national security.

Regrettably, because of the state of my health and my financial condition, it is impracticable for me to travel. It is suggested that if you want further confirmation of the unmatchable economic value of my prime mover that you obtain the cooperation of one or more open-minded physicists deeply interested in providing water for the arid regions of the West and Southwest and well versed in the science of thermodynamics and the kinetic theory of gases to confer with me here at Black Mountain.

Since much of the area of your State has an annual average of less than 10 inches of rainfall and by far the most of it less than 20 inches, why be satisfied with less than all the water you want, even for all your grasslands? The 1,043,000 acre-feet allocated to Wyoming last July under agreement with the other upper-basin States of the Colorado is only a small fraction of the water needed in your part of that drainage area alone. My method promises an abundance for every purpose at prices within the reach of everyone.

This letter with enclosure is sent you with the hope that I can be of service in your obtaining the desired authorization and appropriation from the angle mentioned in the first part thereof. When and if your bill is finally enacted into law I would much appreciate information concerning it from you, the Department of the Interior, or other source.

The production of fresh from salt water and its delivery 1,200 miles inland can be a self-liquidating undertaking if the energy of atmospheric heat is used. It would also not be a difficult matter to prove that it would bring a good profit to the Government over and above the cost of producing and delivering the fresh water. But that is a matter only experts in the economics of electrochemistry, land reclamation, and other applied sciences would be able to determine with any degree of accuracy. However, we know there are at least 3,000 pounds of magnesium alone in an acre-foot of sea water. At 5 cents per pound (it is worth three or four times that much at present) its value would be $150 after extraction. Estimate the potentialities if the value of all the other chemicals and metals are considered. It is certainly a matter worth a thorough investigation.

Incidentally, this new source of energy offers incalculable possibilities in the strengthening of our national defense and especially in revivifying industry, agriculture, and business, thus aborting the next expected serious slump.

The national body economic, jaded, despondent, and edematous is about to take to its bed—the feather variety. No one believes that repeated injections of adrenalin in the form of forced spending will effect a permanent cure. What is needed is confidence in the future and a new esprit free from doubt and defeatism. But a mature body economic is incapable of acquiring them. They can be provided only through the appearance of a new generation—the generation of unlimited power from a new source of supply untrammeled by pyramided costs and restricted production.

Experts in nucleonics have lately given us little hope that primary atomic energy can engender a rebirth of the needed electrifying spirit—the spirit of an economy in rompers. (Sumner T. Pike, of the Atomic Energy Commission, in referring to primary nuclear energy says: "No one need fear that oil or any other reasonably low cost source of energy is going to be supplanted by nuclear energy within any predictable time.")

Fortunately, the general application of secondary nuclear energy—transformed atmospheric heat—sincerely promises to lead to triumphant recovery the forces of constructive cooperation through the impetus of a new, unparalleled, and thrillingly unbounded faith. Our resources are still largely undeveloped despite the maturity of our present economy. Regenerated with unlimited free energy urged upon us by a generous providence it can again become one of youthful effervescence.

Let us avail ourselves of this God-given free energy without delay and open up vast new vistas of opportunity for a tax-ridden Nation burdened with a depression complex.

Yours very truly,

B. A. MOELLER,
Major, United States Marine Corps (Retired).

Appendix II

A Development of Concepts Evidencing the Availability of Atmospheric Thermal Energy

A short discourse in harmony with the second law of thermodynamics as stated by Clausius, Lord Kelvin, and others

If you were one of a thousand men compelled to spend the rest of their lives totally isolated on a tiny mid-Pacific island on which the fresh-water supply was sufficient for only 10 persons, would you resign yourself to the apparent fact that 99 percent of the members of your colony were doomed to die for lack of fresh water? Or would you address yourself to the task of finding a way to make sea water potable?

Some 2 billion of us are marooned indefinitely on a minuscule heavenly body entirely surrounded by an ocean of air containing enough heat energy to supply the human race adequately probably during its entire existence, yet physicists make not the slightest effort now to learn how to tap this energy even though it is far cheaper than any other we shall ever have. Why this inertia? How much effort have they expended in the past in solving this problem? What evidence have we, other than the record of much discussion, often quite animated in nature, bearing generally only indirectly on it in the light of our modern kinetic theory of gasses, and pronouncements largely of a negative character, such as "Heat cannot, unaided by external agency, pass from a colder to a hotter body"? Nothing in this statement indicates the economy of the application of such "external agency," hence it leaves us in the dark as to the exploitability of the heat energy of the atmosphere. It merely reduces by one the number of possible methods by which this energy can be put to use. We are told by another authority that "It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of surrounding objects." There is a world of difference in thermodynamics and the economics of energy between "cooling" a portion of matter and "letting it cool." The former operation requires external energy mainly, and always involves the expenditure of more energy than is gained. The latter requires no direct expenditure of external energy, and may prove exceedingly profitable. In the former case the portion of matter is acted upon. In the latter all barriers preventing the passage of heat are wholly or partially neutralized so that the portion of matter itself can act. We thus see that this latter statement of the second law of thermodynamics also merely adds another restriction to the number of ways in which heat energy can be profitably extracted from the atmosphere but does not assert its impossibility either expressly or impliedly.

Also, some physicists (and engineers) go on to say that since the natural environment furnishes no permanent heat sink with sufficiently low temperature to maintain a flow, the heat energy of the atmosphere cannot be exploited, and cite the latter of the foregoing two statements of the law in support of their contention. They assume that if nature fails to do the job that it cannot be done. It cannot be too strongly emphasized that their interpretation of the latter statement of the law appears to be grossly erroneous, as proved above. When a gas flows into a heat sink its heat energy, in doing work, may be transformed into mechanical energy. But in the process the gas is definitely not "cooled." Instead, it cools or is permitted to cool. No external force is exerted on it in the process, but a force is exerted by the gas itself. When heat is removed the energy expended invariably exceeds in heat-unit equivalents the number of heat units removed. "Cooling" is forcible depriving of heat. Not so when a body cools or is allowed to cool. No heat is removed from the body then by an external force. It leaves without coercion and, under favorable conditions, the heat units voluntarily leaving the body may exceed those expended in clearing the way for the flow of the heat.

If we were to translate these ideas into political terms, we would say that under a dictatorship where all the people are forced to work while offering stout resistance, there is great inefficiency. But under a democracy where they are free, while some effort will be wasted, there will still be a much greater degree of efficiency—enough for real progress to be made.

The unconcern with which this problem has been dismissed bespeaks an assurance that an abundance of energy from other sources will be at our disposal indefinitely. Even so, why the conspiracy of silence in regard to atmospheric heat when all possible sources of future supplies of energy are discussed? Because of the firm conviction it is not available. Would that be your answer if the paucity

of energy today were as great as that of the fresh water in the hypothetical situation mentioned in the first sentence of this letter? I think not. In that situation you would not have argued, "We have only a little fresh water. To freshen salt water we have somehow to wash the salt out of sea water with fresh water. That process will yield us less fresh water than we would expend in the operation. Hence, it would be uneconomical to attempt to freshen sea water." No, you would use a method which does not involve the loss of an appreciable amount of fresh water; e. g., distillation.

Likewise, if absolute necessity dictated the use of atmospheric heat energy, scientists would not argue that the only possible way to utilize it is to use an excessive amount of other energy to extract it. Such an argument is specious and springs from defeatism. This inert reasoning would not be resorted to but for the abundance of energy available from other sources. If the use of atmospheric heat energy were a matter of life or death, some syllogistic approach such as the following would be substituted:

"All energy carried by an accessible vehicle can be made available in part through the instrumentality of some inanimate material means that can be devised by man. Atmospheric heat is carried by an accessible vehicle. Hence, atmospheric heat can be thus made available in part."

It is not becoming to the intellectual prestige of the human race for it to find itself completely surrounded by molecular energy fairly begging to be put to use, and be totally devoid of the wit to apply it for industrial purposes through some inanimate mechanical agency.

We jump to the conclusion that because two portions of matter differ in temperature, heat energy cannot flow from the colder to the hotter without external aid and there let the matter rest. Of course, this is a reasonable conclusion. Our experience tells us so. But why be so sure that we have not overlooked something? Possibly our experience is limited. Possibly our ability to evaluate our experiences in their applicability to this case is defective. Also, possibly our ability to recall all our pertinent experiences before arriving at a conclusion is imperfect. Furthermore, there is no imperative that the energy retain its original form in making the transition.

This is not a discussion of a matter from an academic standpoint nor a quibble over terminology. Physical effects, together with their economic possibilities, are involved, and the fate and happiness of all mankind are at stake. If energy in the form of heat disappears from a relatively cool body and reappears in the form of heat in a hotter body it matters little from a practical standpoint that it can do so only by changing form en route. The fact that such a flow is possible, as proved by common engineering experience, is the point that is worthy of interest in discussing the availability of atmospheric thermal energy. Are we justified merely because of statistics, considering the possibility of error in our logic, in maintaining that we have exhausted the potentialities of the scientific method in our determination of the question?

* * * * * * *

As a result of my research the following propositions are advanced as bases for the formulation of a fourth law of thermodynamics:

1. Statistics, while they may be persuasively suggestive of natural law, do not themselves constitute a fundamental principle and can abrogate none.

2. The economical conversion of the kinetic energy of the molecules of a volume of gas into work in the face of its equality of temperature with its surroundings—involving, as it does, an increase of entropy and decrease of temperature—is purely a technological challenge, not a scientific absurdity, since the potential of each particle usually differs from that of all its neighbors.

3. The problem of making energy available is one of neutralizing resistance to its flow. Neutralization may be effected by action taken in connection with either the energy itself or with its compensation. Heat energy currently unavailable because of isothermalism may logically be released by transformation, thereby substituting a potential different in nature; by physical removal of the compensation—an uneconomical procedure if adopted alone—by introducing a change into the nature of the compensation; or by a combination of two or more of these methods.

4. In transforming energy only a minor part of that involved in the process is normally lost to ultimate use. This rule loses none of its validity because of the circumstance that the energy to be transformed is currently unavailable.

5. Transformation, unlike utilization, is possible below the datum level of zero availability.

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6. An isothermal, gaseous environment, while a perfect barrier to the passage of heat and thus a completely effective bar to its immediate availability, offers no serious resistance to the flow of energy in some other forms into which heat is convertible.

7. The atmosphere is in a metastable state, but only restrictedly so, in that, in order to develop its thermal energy, activation energy must be continuously applied.

The foregoing facts, proved or provable, warrant the assumption that—

(*a*) Transformation is the key to the availability of atmospheric heat energy, for through change in form it is possible economically to establish conditions permitting the development of a potential difference, the sole artificial contribution indispensable to its availability.

(*b*) The heat energy of the atmosphere can, to a limited extent, be made available (because of its resurgeability through transformation and the metastability of its vehicle).

When the last preceding statement is substantiated empirically, it will be found that—

The maximum availability of heat energy is ultimately determinable by kinetic differences between molecules rather than by relative temperatures of masses, for diversity of kinetic potentials among the former continues to afford an effective basis for such availability after temperature equality between the latter, which otherwise would terminate it, has been attained.

BENJAMIN A. MOELLER.

SUPPLEMENT TO APPENDIX II

In clarification of appendix II it is convenient to introduce the theory of progressively resurgent availability. The quality or degree of availability of energy is determined by the number of processes (natural and artificial) to which its vehicle must be subjected before it becomes usable. Energy in a state of primary availability requires no processing. That secondarily available needs to be processed once, etc. All immediately available energy is in a state of primary or actual availability. Atmospheric thermal energy is in a state of secondary or potential availability, because a single (artificial) processing will cause it to become immediately utilizable.

Through the adroit continuous application from without of a quantity of energy in a state of primary availability a much greater amount of (heat) energy only secondarily available can be translated into a primary state without raising the potential (temperature) of the latter; in the case of atmospheric heat energy, merely by releasing it, i. e., neutralizing the factors which keep it in a state of secondary availability. Incidentally, there is no more quantity relationship between the amount of energy expended in releasing atmospheric heat and the amount released than there would be between the number of prisoners confined in a jail and the force necessary to effect their release in the face of hostile opposition. Should we want to release a number of our friends from an apparently impregnable concrete-and-steel dungeon we would not order a regiment of men to butt their heads against the bars behind which our friends are confined because we know that such a direct method would prove barren of profitable results. No; economy-mindedness demands that we use our heads for a different purpose. We are going to gain our end through stratagem practiced on the turnkey. In that way one or two persons can release dozens, who, as soon as released, are added to our force. From a condition of secondary availability the prisoners are, through the efforts of only a fraction of the number released, translated into a state of primary availability.

This parallel explains how we can transpose atmospheric heat energy from the secondary-availability column to the primary-availability column so economically. Atmospheric heat energy also is guarded by a "turnkey."

Thermodynamicists may say, "Well, you can get around a human turnkey through craftiness, but you can't fool inanimate nature," and may add, "when two inanimate things equal in every respect are matched against each other neither will give way or else both will be destroyed; one never prevails against the other." Let us see. We have two rectangular beams that are exact duplicates of each other in strength and every other respect—¼ inch by 1½ inches by 48 inches. Fastened at the ends, they are forced against each other at the middles while at right angles to each other, but the ¼ inch edge of one is squarely in contact with the 1½ inch surface of the other. One, and only one,

breaks. It could have been predicted with absolute certainty which one would, once the conditions had been determined. The inescapable conclusion is that even in inanimate nature the technique alone, when all else is equal, may determine the result. Is it then too much to believe that that also applies to the release of atmospheric heat energy? That when two opposing masses of air are equal in temperature and all other respects that one will yield to the other if the latter is favored in some way in the opposition, such as merely reducing the effectiveness of the resistance against it (thereby establishing a flow). Also that about 95 percent of the atmosphere—a small portion at a time—can thus be caused to surrender its heat energy in the form of work? If so, the atmospheric line does not mark the lowest limit of ultimate availability as allegedly postulated by the second law of thermo-dynamics, but some line at a level where the pressure is far less. Theoretical physics, it has been discovered by me, confirms this assumption.

Transformation does for air, when it is used as an operating fluid in a prime mover, what condensation does for steam, when used as a working substance. The back pressure can be largely neutralized in the case of the flow of energy carried by both gasses, with considerable profit to ourselves.

To make atmospheric thermal energy immediately available we do not have to create it or even raise its quality or potential, but merely to release it—the technique of which is simple and appeals to our good sense when understood. Less than 50 years ago, before aeronautics was understood, proposed sustained human flight in a powered heavier-than-air craft also seemed preposterous to many physicists and engineers.

Ever since the moment 53 years ago when the truism that "the amount of useful work energy will do depends as much on how it is applied and how resistance to its flow is effected as on the amount expended" struck me like a flash, I have been in quest of the secret of releasing atmospheric thermal energy, making it immediately available, improving the technique and the projected utilizer, and verifying my favorable findings. The propositions advanced in appendix II from the basis, in retrospect, for my discovery of a technique which, it is firmly believed, will prove highly effective in developing the energy under consideration.

Senator ANDERSON. A statement by Mr. C. W. Glover follows:

MOON-BEAM CATALYTIC RESEARCH LABORATORY,
Madison Wis., March 6, 1951.

Subject matter: Joint Weather Control Hearings Scheduled by Senate Committees

Mr. MILLS ASTIN,
Chief Clerk, United States Senate Committee on Interior and Insular Affairs, Senate Office Building, Washington 25, D. C.

DEAR MR. MILLS ASTIN: I am personally interested in bill S. 5, which was introduced by Senator O'Mahoney, chairman of the Interior Committee, whose bill is principally concerned with extraction processes in placing the responsibility in the Interior Department. The writer will be unable to appear at the hearing but is pleased to file a statement for the record.

It is my understanding (Senator O'Mahoney's subcommittee consisting of Senator Anderson, Senator Herbert H. Lehman, Senator George A. Smathers, Senator Guy Cordon, and Senator Arthur V. Watkins) the bill under caption S. 5 deals with the extraction of potable water by chemical or mechanical means from sea water; this being the object of the hearings. Thus, I am interested in filing the following statement for the record:

The Moon-Beam Catalytic Research Laboratory, 607 East Wilson Street, Madison 3, Wis., the writer, has discovered a principle of nature for converting inert substances into usable forms of energy. This principle of nature's law could be made use of only by the development of a method of harnessing the principle of nature. Thus, I invented the mechanical catalytic machine with which to employ this principle of nature's law. The combination mechanical catalysts machine which operates by electronic action, etc., renders water zero soft without employing heat, chemicals, or power, even with a continuous flow. Water is a property of matter. This machine is capable of dividing it into its three classes—solids, gasses, and liquids—even with a continuous flow.

The mechanical drawing and specification provide that the machine withstands 150 pounds of internal pressure. The scales are flexible and may be built to any size guided by the volume of water wished to be processed at any given period. Understand, there is no power used, no chemicals used, nor heat. It operates solely by electronic action, etc. The materials used in its construction are always

available in normal times and are, therefore, economical in price. The upkeep could never be excessive.

There is a graduated scale of the components worked out and rationed to handle any specific quantity of water at any given period. The invention was reduced to practical use and industrial use several years ago. During the experimental stage, during my 20 years of research, I have come in contact with a number of methods used and the above method I find to be the most economical and it can do a perfect job as that's the only way any principle of nature works.

Submitted by the Moon-Beam Catalytic Research Laboratory,

C. W. GLOVER.

Senator ANDERSON. The Glare Research Institute has submitted a statement and Senator Dirksen has asked particularly that we include it, and without objection we will include both the letter of transmittal and the statement from the organization.

(The documents above referred to are as follows:)

GLARE RESEARCH INSTITUTE,
Chicago, Ill., March 7, 1951.

Hon. MILLS ASTIN,
Senate Office Building, Washington 25, D. C.

HONORABLE SIR: In reply and compliance with your letter and circular of February 28, I am forwarding, enclosed, six copies of my formal statement in opposition to "legislation involving long-range weather control, artificial production of rain by cloud seeding, or other means" and in favor of "the extraction of potable water by chemical or mechanical means from sea water."

As I do not have any transcripts of S. 5, S. 222, or S. 798, I am unable to differentiate between the first two subjects involving long-range weather control and cloud seeding. However, I am quite positive that these two subjects embrace cloud-seeding methods and are therefore treated as one subject.

Copies of the former hearing on rain making, under H. R. 4582, Eightieth Congress, can be obtained easier by you than they can from this office in time for this hearing. I do not have any record of the hearing before Senator Kilgore, but have been informed by Senator Kilgore that this matter had been referred to the Senate Judiciary Committee about the middle of August 1949. Perhaps this record is also available.

Regarding Francis W. Reichelderfer, Chief of the United States Weather Bureau: According to FBI records, he was at one time a commander in the United States Navy. Dr. Irving Langmuir, of General Electric Co., has been on the staff of the Naval Research Laboratory. Quite apparently, Dr. Langmuir received his information regarding the contra-blue-ray discovery from the Weather Bureau records through Dr. Reichelderfer. Such behavior would involve a conspiracy to defraud this Institute.

At the present time, the rights of the discovery of the contra blue rays are held at the "motherhouse" (Headquarters) of the Jesuit Order in Rome, Italy. The United States Government has forfeited its rights to this discovery and at the present time has no rights to use or abuse this discovery in any manner. The Jesuit Order, organized about the year 1540, is an international organization of Catholic priests, brothers, etc., who specialize in scientific research and discoveries. Since their organization, they have never erred once in their opinions regarding the genuineness of a discovery.

However, in view of the fact that the Senate of the United States will hear evidence regarding the cloud-seeding adventures of the General Electric Co., the Glare Research Institute and the Jesuit order will consider a plea for reinstatement of these rights by the United States Government, providing that such a plea will contain a provision for the punishment of all abusers of this discovery right.

Permission is hereby granted to the Congress (Senate) of the United States by the Our Sunday Visitor, a publication, and the Glare Research Institute to reprint at Government expense, all necessary copies of the article "We Don't Have To Change Genesis Story" without royalty compensation.

Respectfully yours,

G. FRANCIS NAUHEIMER, *Director.*

We Don't Have To Change Genesis Story

In the "Right or Wrong" column of the December 10 edition of Our Sunday Visitor, the statement is made as follows: "Hence if science proves that the material universe existed 100,000 or even a million years before Adam's time the church would find no fault with that." There is no reason whatever for the church to yield even one minute from the written scriptures.

According to the LaPlace, et al., theory that the earth was a fragment of the sun, which took several hundred thousand years to cool down, we find no proof whatever that the sun even existed before the creation of the earth. The question comes up as to just why such a fragment should ever cool down, if, by chance, such a fragment had broken off.

According to the Hubbard-Nauheimer theory of light, we have a far different explanation. This theory is a combination of the glacier explorations of Rev. Bernard R. Hubbard, S. J., better known as the Glacier Priest, and your correspondent's discovery of the contra blue rays.

According to this theory there is no question regarding the assimilation of a great enough quantity of water (hydrogen and oxygen) in one spot to form a planet. In the total absence of light, such a mass of water would be frozen to an absolute solid.

To produce light upon such a solid mass of ice would cause at least partial disintegration (Father Hubbard clearly shows this does still happen in his color-sound pictures of Alaska) which would form an atmosphere and liquid water.

Again we have the creation of soil upon the second day, which also happens in the present glacier areas. Now that we have soil, we also have something for vegetation to establish a foothold, and here the discovery of the contra blue rays proves that the action of chlorophyll in plants produces a reproductive method of counteracting solar light and also forms a continuous process of gas ascent and descent. This is most probably the light referred to on the fourth day.

Next we have the creation of animals to forage on the vegetation and then the final creation of Adam and Eve, as clearly mentioned in Genesis.

There was no such thing as a day at the time of Creation. This period of time could have been 6 months of daylight and 6 months of darkness of the polar regions, or it could have been a fraction of a second. However, in glacier areas it does not take very long for soil to form and vegetation to commence, once the glaciers have disintegrated. Consequently, we do have proof that Genesis did use sound reasoning in the episode regarding the events of the Creation.

Several months ago, George E. Sokolsky, in his column, mentioned that the American Association of University Professors had caused a change in publication of Prof. Immanuel Velkovsky's book Worlds in Collision. A few weeks later, Prof. Paul Herget, of the Cincinnati Observatory of the University of Cincinnati, again in Sokolsky's column, admitted that he was the instigator of this plot. The reason for Professor Herget's attack upon the revelations made by Velikovsky was that it would embrace the revision of textbooks, not because Velikovsky's book might be a step nearer the truth in regard to the origin of Creation.

G. Francis Nauheimer, *Director.*

Glare Research Institute,
Chicago, Ill., March 7, 1951.

Mr. Mills Astin,
Chief Clerk, Senate Office Building, Washington 25, D. C.

To the Senators Sitting in Joint Subcommittee for the Hearing Upon S. 5, S. 222, and S. 798, Otherwise Known as Legislation Involving Long-Range Weather Control, Artificial Production of Rain by Cloud Seeding or Other Means, and the Extraction of Potable Water by Chemical or Mechanical Means From Sea Water:

Gentlemen: In compliance with your letter and circular, advising that a hearing on the above Senate bills will be held on March 14, 15, 16, and possibly March 19, I beg to inform you that a matter of necessity prevents me from appearing in person in Washington, D. C., on the days specified. However, the following statements are to be read into the records of this meeting, together with the attached reprint entitled "We Don't Have To Change Genesis Story," and also my previous statements on pages 39 and 40 of the published record No. 73552, entitled "Rainfall Experiments," H. R. 4582, before the Committee on Interstate and Foreign Commerce, House of Representatives, Eightieth Congress, second session, dated March 18, 1948, as this testimony is the original statements regarding a dispute between the Glare Research Institute and General Electric Co. regarding an illegal use of our discovery rights in the contra blue ray discovery.

TESTIMONY

As my first evidence I want to quote from the column of Drew Pearson dated August 2, 1949, as follows: "The idea of Congress repealing the law of gravity is an old joke. Nevertheless, the Senate actually is studying what laws may be needed to regulate man-made hurricanes.

"The issue was brought up by General Electric, which asked Congress to exempt the company from damage suits for any wind, hail, or rain storms it may cause.

"General Electric is dead serious about this. For it has a contract with the Navy to conduct weather-making experiments in the mountains near Schenectady N. Y., and wants to make sure it is not held responsible in case a bad storm is brewed.

"The Navy appealed to Congress in behalf of General Electric, warning that its experiments 'may cause' certain weather conditions—rain, snow, hail—and even in some instances may develop hurricanes and other high wind storms." End of quotation from Drew Pearson's column.

Considering that the Donora disaster of October 1948 was blamed upon weather experiments involving cloud tampering at the Clinton County Air Force Base at Wilmington, Ohio (see Rainfall Experiments, H. R. 4582, 80th Cong.), General Electric Co. has plenty to worry about. The Drew Pearson evidence is taken from a hearing before a Senator H. M. Kilgore subcommittee.

From the year 1933 until the year 1945, the division of weather research of the Glare Research Institute conducted a long-range weather-forecast service comprising a 1-month and a 3-month summary of long-range weather forecasts, copies of which had been sent to the United States Weather Bureau. From 1933 until 1935, these forecasts were broadcast as a public service from radio station WLS in Chicago. From November 1935 until September 1939, these same types of forecasts were published in the Chicago American, now Chicago Herald American. In all this time, the Glare Research Institute did not receive one penny of compensation from the United States Government to assist in the payment of this research, or to pay any damages resulting from any of this research.

Unfortunately, Dr. Francis W. Reichelderfer, the Chief of the Weather Bureau, during the period of World War II, was personally prejudiced against our research work and failed to include this work in any of his war projects, although we were well aware that several weather projects were in progress, one of which was a weather laboratory in conjunction with atomic research which was located at the University of Chicago, in Chicago. However, it has come to our attention that on numerous occasions, Dr. Reichelderfer has come to the aid of the General Electric rain-making experiments, although he is well aware that these experiments are in violation of our discovery of the contra blue rays.

In our surveys of research in the problem of weather and farming, we find that irrigation is much more preferred to farmers than any type of rain making. In irrigation, the farmer is able to test his water for potency and is also able to regulate the amount of water that he applies to his land. Rain making offers the farmer no assurance that he will get any water upon his land.

On page 13 of the report No. 73552, being the copy of the Rain-fall Experiments under H. R. 4582, Eightieth Congress, we quote from a question by Congressman Heselton to Mr. D. E. Chambers, executive engineer of Schenectady office of the General Electric Co., as follows:

"Mr. HESELTON. Mr. Chambers, it is possible that you do not care to answer these questions. If so, I just want you to indicate it. But, I have here a statement filed in opposition to the bill, which I have hurriedly examined, by G. Francis Nauheimer, director, Glare Research Institute, Chicago, Ill., in which he mentions the General Electric. If I understand his position correctly, there is pending some type of litigation between the institute and the General Electric with reference to the subject matter of these bills.

"Now if that is true, my understanding of the contention is that this process which you have just described, in the absence of suitably controlled formation, is likely to be of no value and further experimentation is useless, and he attempts to demonstrate that by quotations from the World's Popular Encyclopedia, and I think he also indicates that the Department of Agriculture is operating in cooperation with the United States Weather Bureau, and have agreed to that conclusion.

"I think it would be helpful to us, if you care to do so, if you think it is appropriate for you to do so, to make any comments upon that type of opposition to the bill which you care to which is pending before us.

"Mr. CHAMBERS. *I am not informed concerning the litigation that you mention.*" [Italics ours.] "*I have not heard about that.*"

Senator ANDERSON. R. B. Lloyd has submitted a statement that

In regard to the above underscored statement by Mr. Chambers, of General Electric Co., I want to now quote from a letter dated December 6, 1946, originating from the office of Charles E. Wilson, then president of General Electric Co., located at 570 Lexington Avenue, New York 22, N. Y., as follows: "This will acknowledge receipt of your letter of December 2 to Mr. Wilson, on the subject of "the recent cloud-busting experiment by Dr. Irving Langmuir and Mr. Vincent J. Schaefer of our research laboratory in Schenectady.

"Mr. Wilson is away, to be gone until the latter part of the month, but I shall see that your letter is called to his attention at the first opportunity. *In the meantime* [italics ours] *however, I am forwarding copies to our research and engineering people at Schenectady, for their consideration.*

"Very truly yours,

"(Signature) JAMES F. HARRIS,
Secretary to the President."

From this evidence, it can reasonably be concluded that Mr. Chambers lied in the underscored statement. Moreover, from March 18, 1948, when this statement was made, up to the present date, Mr. Chambers, or any other member of the General Electric Co., failed to make any inquiries of the Glare Research Institute, relative to any cause for complaint in regard to the rain-making experiments, and have ignored other inquiries made to the General Electric Co.

Now, with the above evidence in mind, it is the conclusion of the Glare Research Institute that the General Electric Co. is deliberately trying to obtain possession of the contra blue ray discovery by fraud, conceit, and coercion and any legislation to defray any funds from the Treasury of the United States, for this purpose, would make the United States Government, itself, a party to this conspiracy to defraud the Glare Research Institute and its director, who is the discoverer of the contra blue rays, of its sole right by discovery, to the contra blue rays, and the just regulation of the rights to the proper and just use of this discovery by persons who are willing to take advantage of this discovery by properly using these rights in the public interest.

Be it further said: That Dr. Francis W. Reichelderfer, Chief of the United States Weather Bureau, be charged with malfeasance and dereliction of his office, and that he be dismissed from any and all employment in the United States Government service.

* * * * * * *

EXTRACTION OF POTABLE WATER BY CHEMICAL OR MECHANICAL MEANS FROM SEA WATER

In the creation of the earth according to Genesis (see We Don't Have To Change Genesis Story), the earth was created from water, and there still remains about twice as much water as land. The oceans contain a nominal amount of salt, about 6 percent, to preserve this water for future use, and man is entitled to take this water for his needs, as such needs become necessary. The Glare Research Institute endorses the use of this ocean (sea) water and the extraction of the salt and other minerals contained therein to make this water potable for human consumption, or for needs of irrigation to supplement any lack of natural rainfall. The Glare Research Institute has carefully investigated the prior work done by Raymond V. Darby, supervisor of Los Angeles County, Calif., originator of the method, and finds that although quite expensive at first, that the project could be made to pay for itself in the long run.

The United States Navy, and other seagoing ships, have been "desalting" sea water with great success for the past 40 or more years. Several processes could be employed to desalt sea water and choice of method should be left to the community or local terrain where the sea water is to be desalted. However, we do favor the Chicago plan of water withdrawal (in Chicago, water is withdrawn from Lake Michigan which is not salt) using several cribs for each area. This method operates very satisfactorily as the breaking down of one unit, perhaps due to storms, would not deprive that particular area completely of water. Pipelines could be run into the interior States for irrigation purposes, or recleaned waste waters from California cities could be piped into the Colorado and other rivers for reuse in irrigation.

Desalting of sea water would not place the contra blue ray discovery in jeopardy in the manufacturing fields and is therefore approved by the Glare Research Institute.

G. FRANCIS NAUHEIMER,
Director, Glare Research Institute.

Senator ANDERSON. R. B. Lloyd has submitted a statement that will go into the record.

(The statement of Mr. Lloyd is as follows:)

LOS ANGELES, CALIF., *March 9, 1951.*

Mr. MILLS ASTIN,
Chief Clerk, Senate Office Building, Washington, D. C.

DEAR SIR: I received your letter of February 28, 1951, with the press release describing weather control hearings scheduled to open March 14.

I will not be able to go to Washington for the hearings (S. 1300), but I would like Senator O'Mahoney to ask the Bureau of Standards to check and answer any questions regarding the cost of sea water evaporation as shown in the enclosed copy of my letter to the Senator dated August 12, 1949.

The Reclamation Bureau has records of the salt content of the lower Colorado River (referred to in my letter) before Boulder Dam was built. My information was received nearly 50 years ago from one of the Bureau's engineers, Mr. Maxwell.

Yours respectfully,

R. B. LLOYD, *Supervising Engineer.*

P. S.—My regards to the Senator.

AUGUST 12, 1949.

Subject: Sea water.

Hon. JOSEPH O'MAHONEY,
Senate Office Building, Washington, D. C.

DEAR SENATOR O'MAHONEY: (1) This news item is one of many of recent date regarding the distilling of sea water for domestic and irrigation use, but it is not believed possible at reasonable costs.

(2) One pound of our (average) oil will evaporate 10 pounds of water (steam) and this 10 pounds of steam (by weight) will distill 25 pounds of sea water using the steam in coils and the sea water in a tank with vacuum equipment.

(3) One million gallons of sea water weighs 8,300,000 pounds (approximate) and at 25 pounds of water per pound of oil, 332,000 pounds of oil would be required.

(4) The quoted price of oil on January 1, 1949, was $2.56 per barrel of 337 pounds (and as reported will cost $5 per barrel in 10 years) and would require 985 barrels for 1 million gallons (distilled) water or costing $2,521.60 (at $2.56 per barrel).

(5) Los Angeles' water consumption is 300,000,000 gallons daily and the daily cost of fuel (only) would be $756,480 per day.

(6) The total cost in 5 years would pay for a 1,500-second-foot conduit and tunnel from the Columbia River for southern California and part of Arizona. The Bureau of Standards should check this statement for you.

Yours respectfully,

R. B. LLOYD, *Supervising Engineer.*

P. S.—(1) Yes. Build those upper Colorado River dams and give Arizona first call for all the power they can use within the State (and pay for as California is doing with Boulder power). But don't take the only fresh water (from Los Angeles) that is going into Boulder Lake. This is snow water from the west slope of the Rocky Mountains.

(2) If this "Arizona diversion plan" is put over, the remaining flow from the Virgin River, and the other streams from thousands of miles of salt plains will be unfit for anything but power.

(3) Before the dam was built, the Colorado River at Parker carried 3,000 parts per million gallons of salt, June to November (4 tons per acre-foot, see United States records). The flow now carries 800 parts per million, and the "pee-wee" oranges show what this salt is doing to the orchard.

R. B. L.

Clifford K. Denman (architect), 5749 South Wilton Place, Los Angeles, Calif., confirms this letter and agrees with me that your advisers should know how foolish this sea water plan is.

Senator ANDERSON. The Sea Water Corp. of San Diego statement will be incorporated in the record.

(The document above referred to is as follows:)

SEA WATER CORP,
San Diego, Calif., March 8, 1951.

Hon. JOSEPH O. O'MAHONEY,
Senate Office Building, Washington, D. C.

HONORED SIR: This is to acknowledge with thanks the notice of February 28 relative to hearings beginning on March 14 on S. 5 as well as S. 222 and S. 798 dealing with weather control and rain making.

We would like to see it emphasized at these hearings that sea-water conversion does not compete with rain making nor substitute for it. Nevertheless the extraction of fresh water and vital minerals from sea water is still all-important as a strategic and economic measure, and it can be done at times and in places where rain making is not possible.

Members of Sea Water Corp. of San Diego are pioneers in bringing the importance of sea-water conversion and its all important side line of minerals to the attention of President Harry Truman and Secretary of the Interior Oscar Chapman as well as the general public. The enclosed letter as well as the latest report on the newest and most economic sea-water conversion still show what is being done with almost no finances devoted to research.

You may be interested to know that already we have received numerous personal answers indicating support of these bills when they come to the floor of the Senate and House. Notable among these letters are those from Senators Carl Vinson, Carl Hayden, Guy Gordon, Sam Rayburn, Wayne Morse, J. W. Fulbright, Harley Kilgore, and Representatives John Murdock, Emanuel Celler, Fred Marshall, Reva Bosone, and Clair Engle.

We regret more than you can know our financial inability to appear before your august hearings and plead for support of these bills but the "silence of the great unheard constituents" may be more eloquent than our actual presence. As a last thought, is it absolutely impossible to persuade you to hold at least one hearing on the sea-water bill here in San Diego, the city of greatest need for such Government-sponsored research? You realize, of course that to launch such research may prove to be one of the greatest investments of all time.

At least thank you for your help.

Respectfully yours,

ROBERT J. MCPHERSON,
Secretary and Cofounder, Sea Water Corp.

SAN DIEGO CALIF., *December 26, 1950.*

HONORED SIR: In March 1949 Representative Clinton D. McKinnon of San Diego, reelected last month, introduced into the House H. R. 3123. I am writing to you at this time to urge you to study this important H. R. 3123, if you have not already done so, and then help to get early action on it. The purpose of the bill is "to conserve and increase the Nation's water resources, to strengthen the national security and common defense by authorization of research and demonstration of practical means of producing from any saline waters, sea or otherwise, water suitable for consumptive use, and other purposes."

H. R. 3123, like its companion, S. 1300 in the Senate by Senator Joseph O'Mahoney, of Wyoming, when enacted, can prove to be two of the most potentially important bills ever presented in the Congress of the United States. Such research is absolutely essential to the future of this Nation due to two interrelated factors. According to the authorities on the subject, the rainfall across the Nation is decreasing each year, and the water table is dropping everywhere to points lower than ever before. In addition, new types of industry are using colossal amounts of fresh water. A recent ad by a maker of nylon states that one plant alone uses 100 million gallons a day.

That these bills were presented at this time is largely due to the efforts of the writer, through the Sea Water Corp. of San Diego. In a small local laboratory,

through personal sacrifice, our group already has discovered one method of producing fresh, soft water from the ocean at a cost much lower than many people believed possible. However, our funds are limited, and unless we can obtain some financial aid, such as provided for in these two bills, tests and development of an economical means to convert sea water into fresh water may be delayed indefinitely.

Another thought for you to consider is that through the use of fresh water from the ocean, sea coast cities may not have to drain away water from inland cities.

For these reasons let me urge you again to study H. R. 3123 and then help speed action on it. Incidentally, the bill is not very long. In this way you can feel that you had a hand in one of the great achievements of modern times—the direct use of the ocean to relieve drought—and at the same time help to accomplish one of the four freedoms—freedom from want.

Thank you for your time and help.

Respectfully,

ROBERT J. MCPHERSON.

The Mechanical Equipment Co. of New Orleans, represented on the west coast by Sea Water Corp., announces that it was awarded a contract recently by the Corps of Engineers, United States Army, for the world's largest thermocompression water-distillation plant which is being installed at an undisclosed destination. Following are some of the statistics of this newest plant:

(*a*) Capacity: During test averaged 57,000 gallons distilled per day.

(*b*) Efficiency: When using fresh water as feed, 24.2 gallons of distilled water per kilowatt-hour, when using salt water as feed, 22.9 gallons per kilowatt-hour.

(*c*) Purity: Approximately 2 parts per million NaCl when using salt water as feed.

(*d*) Boiler fuel consumption: Approximately 3 gallons per hour.

(*e*) Temperature differential: With feed water at 70° F. distilled water was not in excess of 79° F.

(*f*) Power: Vapor compressor driver by 250-horsepower electric motor which was required by contract. With use of brine-stabilizer equipment to reduce scale formation could use motor on considerably less horsepower, approximately 225, and still operate several months between cleanings. The feed pump is driven by a 3-horsepower motor; the distillate and blow-down pumps by 2-horsepower motors, and the brine stabilizer pump by a 20-horsepower motor.

(*g*) Operating characteristics: After plant is brought into production by hand control, it is entirely automatic in operation. It is protected from damage by several safety devices which stop the plant should anything interfere with its normal operation.

This same general design and output capacity plant, Diesel-driven model SD2100A, is estimated to produce distilled water at a fuel-to-water ratio of about 350 gallons to 1 gallon of Diesel fuel plus about 16.7 kilowatt-hour electricity for driving pumps. The model SN2100A, natural gas engine drive, would produce approximately 1,440 gallons of water per 1,000 cubic feet gas plus the same kilowatt-hour electricity.

This is the latest information available. I hope this will help you.

Very truly yours,

SEA WATER CORP.,
ROBERT J. MCPHERSON, *Secretary.*

DESCRIPTION AND COSTS OF MECHANICAL EQUIPMENT CO. UNITS

Three hundred gallon-per hour unit. Model PD300–E thermocompression distillation (portable). Used extensively in Arabian Desert and Persian Gulf operations by American Independent Oil Co., Trans-Arabian Pipeline Co., Superior Oil Co. Also being used by the Humble Oil & Refining Co. and the Magnolia Petroleum Co. to supply fresh water for their drilling operations on the Continental Shelf, several miles out in the Gulf of Mexico, off the coast of Louisiana.

Output: 50 gallons of water per day per person for 144 people. Cost, 7.3 cents per person.

Operating cost over 18-month period under actual service conditions

1. Annual depreciation ($17,500 for 20 years)	$1, 750. 00
2. Annual depreciation of installation cost	80. 00
3. Supplies:	
(*a*) Diesel fuel at 8 cents per gallon	813. 20
(*b*) Lube oil at 80 cents per gallon	56. 00
(*c*) Miscellaneous	20. 00
4. Operation (part-time operator)	550. 00
5. Maintenance:	
(*a*) Parts	150. 00
(*b*) Chemicals for cleaning	519. 80
6. Total cost per year	3, 939. 00
7. Distilled water output: 2,693,000 gallons per year (310 gallons per hour for 362 days, 8,688 hours).	
8. Distilled water cost:	
Per gallon	0. 001462
Per 1,000 gallons	1. 462
Per barrel	0. 0614

NOTES.—(*a*) Diesel engine (33 horsepower) drives vapor compressor, feed and distillate pumps, and supplies make-up heat to evaporator; (*b*) load during normal cycle: 14 to 26 horsepower; (*c*) average load: 20 horsepower; (*d*) average ratio: 265 gallons of distilled water per gallon of fuel; (*e*) initial cost: $2.43 per gallon of daily output capacity.

100,000-gallon-per-day unit. Model SD–100000–A thermocompression distillation:

Purchase price	$175, 000
Installation cost	5, 000

Output: Domestic consumption: 50 gallons a day to every man, woman, and child in community of 2,000. Cost per person, 2.7 cents per day.

Irrigation measurement: 1 acre-foot every 3 days, the equivalent of 28 inches of rainfall annually over 50 acres; or 14 inches (more than the normal average in San Diego County) over 100 acres.

SEA WATER CORP.,
San Diego, Calif.

OCTOBER 1, 1950.

Water-rate comparisons

SAN DIEGO CITY WATER

	Household		Commercial and industrial	
	Per 100 cubic feet	Total cost	Per 100 cubic feet	Total cost
First 500 cubic feet	$0. 306	$1. 530	$0. 306	$1. 530
Next 4,500 cubic feet	. 293	13. 185	. 293	13. 185
Next 5,000 cubic feet	. 281	14. 050	. 281	14. 050
Next 10,000 cubic feet	. 268	26. 800	. 268	26. 800
Next 20,000 cubic feet	. 230			
Above 30,000 cubic feet			. 205	
For 23,560 cubic feet		54. 188		48. 300
1 acre-foot (43,560 cubic feet)		109. 753		103. 865
In excess of 1 acre-foot			. 179	77. 970

Not included in above costs: 14 cents per $100 assessed valuation levied on property for membership in San Diego County Water Authority; "Hidden" expenses: Monthly charge for water softener or costs of packaged softeners; purchase price of acidizers for gardens to neutralize alkali in Colorado River water; 78 cents for 5 gallons bottled distilled water (Puritas), or $156 for 1,000 gallons; or $50,832.60 per acre-foot.

Fresh water made from sea water

Mechanical Equipment Co. units	Per 1,000 gallons	Per acre-foot	Per barrel
Diesel (300 gallons per hour)[1]	$1.46	$481.24	$0.614
Natural gas (100,000 gallons per day)	.46	149.76	
Diesel (100,000 gallons per day)[2]	.55	180.49	

[1] Figures are based on 18 months' check of operation under actual service conditions.
[2] Check of operation for 18-month period is now under way, and it is believed this figure will be reduced by half.

Included in above costs: Amortization (over 20-year period) of purchase price and installation costs; fuel, operating supplies, maintenance costs, operator's salary; that is, total production costs.

Senator ANDERSON. Encino Water Research Group has a letter dealing with that same matter that will be incorporated in the record at this point.

(The letter above referred to is as follows:)

ENCINO WATER RESEARCH GROUP,
Encino, Calif., March 6, 1951.

UNITED STATES SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D. C.

(Attention of Mr. Mills Astin, Chief Clerk.)

DEAR MR. ASTIN: Your letter with the inclosed press release received. We are sorry that we are unable to appear at the hearings, and we will therefore file a statement to be attached to bill S. 5.

Here it is:

A. We utilize activated adobe clays only, in the deionization of raw sea water into fresh water.

B. One square foot of activated adobe clay will deionize 1 square foot of raw sea water daily.

C. Once in 10 days it has to be regenerated with the proper regenerant to continue the deionization cycle.

D. The potable or fresh water is pumped to storage reservoirs to be used for agri-purposes. The regenerant effluent brine is flocculated with calcined dolomite, which is properly slaked, dewatered, and filtered dried. Magnesium hydroxide is the resulting product which pays for the deionization of the sea water. We realize a good profit from the recovery or extraction of magnesium hydroxide, plus deionized potable water free of any cost.

E. The calcium chloride wash water properly treated is converted to a low-cost liquid fertilizer, good for agricultural purposes.

F. Of special interest is the activated adobe clay. It possesses phenomenal absorptive powers and is of infinite use in the profitable recovery of useful minerals and fresh water from sea water.

All laboratory work is completed. We are ready and waiting for your instructions.

Sincerely,

STANLEY B. SHUSTACK,
President, Encino Water Research Group.

Senator ANDERSON. The Griscom-Russell Co. has submitted a statement dealing with the production of fresh water from salt water, which will be incorporated in the record at this point.

(The statement referred to above is as follows:)

THE GRISCOM-RUSSELL CO.,
New York, March 13, 1951.

Subject: Joint Weather-Control Hearing Committee Interior and Insular Affairs, United States Senate.

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
Senate Office Building, Room 224, Washington, D. C.

DEAR MR. ASTIN: We wish to thank you for your letter of March 7th attaching the mimeograph sheet outlining the proposed joint weather-control hearings scheduled to take place March 14, 15, 16, and 19.

We are attaching our statement with regard to reclamation of sea water, which we believe will be of interest to the committee.

We do not intend to have any of our personnel available as a witness at this hearing but would appreciate having a representative present during the hearing of the 19th of March; namely, Mr. S. F. Maury.

Very truly yours,

THE GRISCOM-RUSSELL CO.,
KENNETH B. RIS, *President.*

THE GRISCOM-RUSSELL CO.,
March 13, 1951.

Subject: Reclamation of sea water.

UNITED STATES SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Senate Office Building, Washington, D. C.

GENTLEMEN: (1) Water shortages resulting from increased demand or from occasional dry spells may be alleviated in a number of ways. In some localities artificial rain making may be useful while in others additional dams and aqueducts might be the best solution. For those communities located near the sea, the conversion of sea water into fresh water offers considerable promise. Many methods have been proposed for accomplishing this conversion, but there is wide agreement that distillation is by far the most reliable. It is the only method which is sufficiently well developed to offer an immediate solution. It is at least comparable in cost and has certain advantages not possessed by any of the other methods. Even for those communities removed from the sea, distillation offers a solution to the problem of drinking-water shortages resulting from contamination of normal water supplies in the event of war.

2. Production of fresh water from sea water by distillation is a very old art. We have been engaged in this art since the very inception of our company over 80 years ago. In cooperation with the United States Navy, we have made many advances since World War I and during World War II, so that now we know a great deal about the production of pure drinking water from sea water, particularly by the low-pressure distilling method, which has proven to be the easiest and simplest to operate.

3. Between January 1, 1935, at which time the modern shipbuilding program got under way, and June 1, 1950, our company produced 3,478 distilling plants of low-pressure submerged-tube type ranging in sizes from 4,000 gallons per day to 60,000 gallons per day, having a total rated capacity of 38,066,000 gallons per day. We received several commendations from the Bureau of Ships and the Bureau of Medicine and Surgery praising the successful operation of our plants.

4. In addition to the marine work, we have done a great deal of work on land-type plants evaporating sea water, but most of these have been at higher pressure. One typical plant has now been in successful operation on the island of Aruba for many years producing about 450,000 gallons per day, starting with high-pressure steam in the first effect and going down to low vacuum in the final effect.

5. As a result of recent widespread interest in this subject, a number of novel distilling-plant arrangements have been proposed. Among these, one would combine distilling plants with solar heaters; another would combine them with thermal-difference power plants, and so forth. Quite apart from the natural inherent limitations in the possible application of these methods, none is so well developed to permit immediate relatively large-scale installations to be made now. A great deal of additional time and effort necessarily must be spent on laboratory and small-scale research work.

There are two distillation methods which have been well developed, and which reasonably can be expected to produce relatively large quantities of potable water now. These are (1) low-pressure multiple-effect distilling plants associated with back-pressure turbines, and (2) engine-driven compression-type units.

6. Our preliminary studies have shown that low-pressure evaporators could be associated with back-pressure turbines using multiple effect to economize on fuel, and the installed cost of such an evaporator plant would be about $2 per gallon per day when such plant was built in connection with a 50,000-kilowatt turbine which would produce 4,650,000 gallons per day of distilled water. The extra fuel consumption over that normally required to produce the power would cost approximately 35 cents per 1,000 gallons of fresh water produced. Improvements which may be effected as a result of further development work could well reduce this fuel cost to the neighborhood of 30 cents per 1,000 gallons.

7. For peacetime operation one large central plant would no doubt be the cheapest thing which could be installed, but this is open to other disadvantages in case of war.

8. If it were decided that emergency operation under threat of attack during war is the most important, then widely dispersed plants might be the best answer. For a large number of independent units engine driven compression-type plants similar to those used during the war might offer the greatest safety although the over-all cost would probably be greater. So far such plants have been built in relatively small sizes and considerable research would be required before plants large enough could be built. In particular, the older type of compression plants because they operated at relatively high pressures, were subject to fouling. A low-pressure compression-type plant has been designed and much development work has already been accomplished. This would be a real improvement because the low-pressure plant would operate for longer periods of time without requiring cleaning.

9. For the combination of large volume production at reasonable cost together with safety, perhaps distilling plants should be located adjacent to all of the existing power plants plus a certain number of isolated compression plants remote from the power plants which could still operate in case the power plants themselves were attacked.

10. For distillation plants of the types mentioned above we have advanced beyond the necessity of doing laboratory research. What is now required is the letting of a contract to a qualified manufacturer of distillation units such as ourselves which would permit us to proceed at once with the construction and operation of large scale pilot plants. For this purpose we would suggest a flash-type plant capable of producing about 1,000,000 gallons per day and a compression-type plant capable of producing about 50,000 gallons per day. Our engineers are fully competent to design such plants and we know that we could operate them successfully and, therefore, develop data which would enable us to develop full scale plants on the most economical basis for the requirements of a large city.

Yours very truly,

THE GRISCOM-RUSSELL CO.,
KENNETH B. RIS, *President.*

Senator ANDERSON. The Northern Arizona Range Improvement Co. has sent in a statement which will be printed in the record. It is its theory that seeding has reduced the amount of rainfall in the State of Arizona on its ranges.

(The statement above referred to is as follows:)

NORTHERN ARIZONA RANGE IMPROVEMENT CO.,
Winslow, Ariz., January 29, 1951.

Hon. CLINTON P. ANDERSON,
Senator from New Mexico, Washington, D. C.

DEAR SIR: I have read with a great deal of interest your efforts to secure statutes regulating so-called rain making as a Federal proposition, and would like to greatly compliment you on your foresight and consideration for the welfare of the people of the Southwest.

First, I would like to give the experiences we had in rain making. We organized the Northern Arizona Range Improvement Co. as a corporation to engage in rain making by cloud seeding. We employed the Precipitation Control Co., of Phoenix, to seed clouds with silver iodide from airplanes. During the early part of July 1950, the area comprising Navajo County had considerable moisture-laden clouds for a period of about 18 days. Just before the seeding operations commenced we had several good storms, but needless to say following cloud-seeding operations, the few storms we had were merely grass-burners, because the cloud seeding dispersed the clouds so widely that no beneficial rain could fall. In many instances heavily moisture laden clouds were entirely dispersed, and on several

instances within my personal knowledge, and while a good rain was falling, the cloud seeding immediately dispersed the clouds and stopped the rain.

It is our opinion that a great deal of the present drought condition has resulted from cloud seeding. I believe that one area may take rain away from another. On account of this last proposition Federal laws are undoubtedly necessary.

I note also that the legislature of the State of New Mexico presently has legislation pending before it with reference to regulation of cloud seeding; legislation will shortly be pending before the Arizona Legislature to regulate cloud seeding and rain making.

It is our thought, after considerable study on the subject, that rain making for the present should be conducted only by scientists under the jurisdiction of the United States Weather Service or some university, and should be restricted to small experimental areas.

In the event you wish testimony of actual observations as to the results of cloud seeding, I should be very glad to furnish testimony in the form of a deposition or in the form of affidavits.

I trust you will not deem our organization presumptuous in writing this letter, but we do feel that it is a matter of economic survival for the entire Southwest and perhaps even other areas.

Very truly yours,

C. D. McCauley,
Secretary-Treasurer, Northern Arizona Range Improvement Co.

Senator Anderson. Then there is a statement from Cleaver-Brooks Co.

(The statement above referred to is as follows:)

Cleaver-Brooks Co.,
Milwaukee, Wis., March 15, 1951.

Reference: Bill S. 5.

United States Senate Committee on Interior and Insular Affairs,
Washington, D. C.
(Attention: Mr. Mills Astin, Chief Clerk.)

Gentlemen: As invited by you in your wire of March 13, we are submitting a statement giving our opinion on the extraction of potable water from sea water. This subject is to be discussed on March 19 in reference to bill S. 5.

The production of potable water from sea water has received much attention and a great deal of study through the years. It has been generally conceded that evaporation of sea water by means of vapor compression evaporation is by far the most economical means of doing the job, so we will limit our discussion to this method.

At the present time the problem is simply one of economics. In some localities in the world and even some in the United States, the production of potable water by vapor compressor evaporation is the cheapest method of obtaining a suitable supply.

On the other hand, by no stretch of the imagination, can it be concluded that this method can compete with existing sources. This is best explained by examining the costs which follow:

Costs per 1,000 gallons for producing fresh water from sea water by vapor compression based on a plant for 10,000 gallons per hour

	Compression distillation	
	Diesel engine plant	Electric motor plant
Plant cost, erected without buildings (nonferrous construction)	$500,000.00	$450,000.00
Amortization, basis 15 years	.42	.38
Steam cost, based on fuel at $0.06 per gallon	.00	.14
Diesel fuel cost, based on fuel at $0.07 per gallon	.28	.00
Electric power cost, based on power at $0.003 per kilowatt	.01	.18
Cooling water cost at $0.12 per 1,000 gallons	.00	.00
Lubricating oil at $0.70 per gallon	.04	.01
Descaling heat transfer surfaces	.02	.02
Maintenance and repair	.09	.04
Operating personnel and supervision	.35	.35
Total, cost	1.21	1.12

These figures show the present-day estimated costs for the construction of a 10,000-gallon-per-hour plant and the cost of producing 1,000 gallons of water by these plants.

Column a shows a Diesel engine driven plant while column b shows an electric-motor-driven plant. The fuel for the engine has been taken at the lowest price at which it is available any place in the United States. Electric power has, likewise, been taken at the lowest rate available in the Pacific Northwest.

These figures show that the Diesel-engine plant will produce water at a cost of $1.21 per thousand gallons. The electric-motor-driven plant will produce water for a cost of $1.12 per thousand gallons. These figures ordinarily must compare with the $0.12 rate which is an average figure throughout our whole country. On the other hand, several communities in California would be glad to pay over $1 per thousand gallons to obtain a suitable source.

Many arid sections of the world, such as Saudi Arabia, North Africa, Southwest Africa, parts of Australia and many Pacific islands now use vapor compression evaporators to produce their potable water.

From a study of the costs, the conclusions appear obvious, both for and against conversion of sea water. If the committee would appreciate information in greater detail, we will be happy to oblige.

Yours very truly,

CLEAVER-BROOKS CO.,
JAMES M. STURMAN.

Senator ANDERSON. The Department of the Navy has corresponded voluminously on the subject.

(Subsequently the following letters were received:)

DEPARTMENT OF THE NAVY,
BUREAU OF SHIPS,
Washington D. C., April 25 1951.

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
Senate Office Building, Washington 25, D. C.

DEAR MR. ASTIN: In accordance with our recent telephone conversation at the conclusion of the joint hearings on the three Senate bills, relative to sea-water distillation and cloud seeding, I am pleased to forward herewith for the record, copies of correspondence addressed to various outside activities who have indicated an interest in this subject.

It is believed that some of the testimony presented either orally or in writing at the hearings may have been derived from statements contained in the attached enclosures.

The undersigned would appreciate receiving copies of all written testimony submitted only as regards extraction of fresh water from sea water.

Sincerely yours,

HENRY E. BETHON.

Mr. H. A. HENSON,
Atlanta, Ga.

DEAR MR. HENSON: Your letter of September 25, addressed to the Secretary of the Navy regarding economical conversion of sea water to fresh water has been referred to this Bureau for appropriate action.

The Bureau of Ships is not directly interested in the large-scale conversion of sea water except for shipboard distillation but has been collaborating with the Department of Interior (Mr. Goodrich W. Lineweaver, Assistant Commissioner of the Bureau of Reclamation) in the further pursuit of this work. The Department of Interior has been assigned the over-all responsibility in coordinating the work of the various governmental departments interested in this program.

Although Congress has not yet enacted legislation which would authorize the Department of the Interior to prosecute this work further, the Government is interested in receiving any ideas on an economical way of converting sea water to fresh water suitable for irrigation, industrial and drinking purposes, among others on a large-scale basis.

The Bureau of Ships is also interested in any improved method of converting sea water to fresh water for potable and boiler feed make-up purposes insofar as shipboard installations are concerned.

Furthermore the Bureau would welcome the opportunity of reviewing information on the particular scheme you have in mind and will be pleased to forward same to the Department of Interior if it warrants further consideration.

Sincerely yours,

Mr. FRANK ZITO,
Fairfield, Ala.

DEAR SIR: Your letter of September 1, 1950, addressed to the President of the United States has been referred to the Bureau of Ships, Department of the Navy for appropriate action.

Shipboard distillation is accomplished either by low-pressure (vacuum) steam or by vapor (thermal) compression distilling plants. In general, Diesel-driven vessels are equipped with Badger motor-driven vapor compression plants of either 1,000 or 2,000 gallons per day capacity whereas large steam-turbine-driven vessels are equipped with two or more multiple effect low-pressure (vacuum) steam distilling plants ranging in capacity from 4,000, 8,000, 12,000, and 20,000 gallons per day double effect to 20,000, 30,000, and 40,000 gallons per day triple-effect units. The low-pressure steam plants normally utilize surplus auxiliary exhaust steam, the latent heat of which would otherwise be discharged overboard via the main and/or auxiliary condensers. Under these conditions, the operating cost of producing distilled water is reduced to a minimum.

On the basis that no surplus auxiliary exhaust steam is available, 1 pound of fuel oil will normally yield from 30 to 35 pounds of fresh water for a triple-effect plant and from 21 to 25 for a double-effect plant. In the case of gasoline-engine-driven vapor-compression plants, a fuel economy of from 150 to 165 pounds of water per pound of fuel, which is equivalent to approximately 55 cents per 1,000 gallons, is attained.

The operation of low-pressure (vacuum) multiple-effect distilling plants coupled with the introduction of boiler compound and corn starch has been most satisfactory. Reports have been received that distilling plants have operated for as long as 18 months without pulling the tube bundles out for descaling.

The scheme you propose of redistilling the drains by use of emergency evaporators is neither practical nor economical for shipboard application inasmuch as the drainage piping system would be unnecessarily complicated and furthermore no appreciable savings in steam or improvement in operation will be realized when evaporating contaminated drains as compared with sea water. The policy of the Bureau of Ships is to provide vessels with multiple-effect low-pressure distilling plants of adequate capacity that will amply take care of the fresh-water demand for all purposes.

In case you desire further detailed information on Navy-type distilling plants, the following chapters of the Bureau of Ships Manual can be obtained from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., at a nominal price: Chapter 58 (sec. I), low-pressure steam distilling plants; chapter 58 (sec. II), vapor compression distilling plants.

Sincerely yours,

_____.

Capt. FRANK LUCKEL,
United States Navy (Retired),
Member of Assembly, Seventy-eighth District,
1036 Savoy Street, San Diego 7, Calif.

DEAR SIR: The Bureau of Ships acknowledges receipt of your letter of August 25, 1950, requesting information on the conversion of sea water to fresh water on a large scale for irrigation purposes.

Distilled water may be produced from sea water by one of two general methods namely: ion exchange and distillation. The former method is entirely too expensive to justify further consideration at this time. Other methods such as solar radiation, ultra-high frequency, etc., have been considered but it has been finally concluded that the distillation of sea water constitutes the only practical and feasible method for large-scale sea-water conversion.

As you probably know, shipboard distillation is accomplished either by low pressure (vacuum) steam or by vapor (thermal) compression distilling plants. In general, Diesel-driven vessels are equipped with Badger motor-driven vapor-compression plants of either 1,000 or 2,000 gallons per day capacity whereas large steam turbine-driven vessels are equipped with two or more multieffect low-pressure (vacuum) steam distilling plants ranging in capacity from 4,000, 8,000, 12,000, and 20,000 gallons per day double effect to 20,000, 30,000, and 40,000 triple-effect units. The low-pressure steam plants normally utilize surplus auxiliary exhaust steam, the latent heat of which would otherwise be discharged overboard via the main and/or auxiliary condensers. Under these conditions, the operating cost of producing distilled water is reduced to a minimum.

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The installation of multiple-effect units results in substantial increases in distilled water yield per input unit of heat energy. The heat energy required to produce 1 pound of water for various types of distilling plants is as follows:

	B.t.u. per pound
Single effect, low-pressure steam	1,040
Double effect, low-pressure steam	565
Triple effect, low-pressure steam	370
Vapor-compression plant (one-third blow down)	69

On the basis that no surplus auxiliary exhaust steam is available, 1 pound of fuel oil will normally yield from 30 to 35 pounds of fresh water for a triple-effect plant and from 21 to 25 for a double-effect plant. However, in the case of a steam plant employing bleed steam from a turbine as the heating steam after the steam has performed work in generating power, it is estimated that the economy of a double-effect plant based on an initial steam turbine condition of 415 pounds per square inch and 700° F. will be 70 pounds of fresh water per pound of fuel oil for a bleed point pressure of 5.0 pounds per square inch. A triple-effect plant will result in yields approximately 50 percent greater. In the case of a gasoline-engine-driven vapor-compression plant a fuel economy of from 150 to 165 pounds of water per pound of fuel, equivalent to 55 cents per 1,000 gallons, is attained.

Preliminary studies have shown that low-pressure evaporators could be associated with back-pressure turbines (topping plants) using multiple effect to economize on fuel. The installed cost of such a distilling plant would be about $2 per gallon per day when such plant was built in connection with a $50,000 kilowatt turbine which would produce upwards of 4,650,000 gallons per day of distilled water. The extra fuel consumption over that normally required to produce power alone would cost in the neighborhood of 30 cents per 1,000 gallons of fresh water produced.

In order to realize the maximum economy possible, it may prove advantageous to combine a noncondensing turbine-driven vapor compression distilling unit with a multiple-effect low-pressure (vacuum) steam distilling plant operated by the turbine exhaust steam. Superimposed on top of this combination plant, would be a solar-energy heat exchanger which coupled with high-vacuum multiple-effect distillation could yield large volumes of fresh water at minimum cost.

You are advised that Commodore H. A. Schade, United States Navy (retired), now Director of Engineering Research at the Institute of Engineering Research of the University of California, has recently prepared a comprehensive preliminary proposal for research in the field of sea water conversion entitled "Technical and Economic Investigation of Certain Schemes for Producing Potable Fresh Water From Sea Water, UCB–Eng–331."

In case you desire further detailed information on Navy-type distilling plants, the following chapters of the Bureau of Ships Manual can be obtained from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., at a nominal price:

Chapter 58 (sec. I)—Low pressure steam distilling plants.
Chapter 58 (sec. II)—Vapor compression distilling plants.

As regards further evaporator design data and distillation costs for various types of plants, it is suggested you contact Badger Manufacturing Co. (Mr. John J. Campobasso) and/or Arthur D. Little, Inc. (Mr. Allen Latham) both of Cambridge, Mass. for vapor (thermal) compression distilling plants and the Griscom-Russell Co. (Mr. Sifrein F. Maury) of 285 Madison Avenue, New York City for low-pressure (vacuum) steam multi-effect distilling plants.

Sincerely yours,

Mr. VALERO FERNANDEZ, Jr.,
Club Nautico de Marianao, Marianao, Habana, Cuba.

DEAR SIR: Your letter of May 10, 1950, relative to sea-water conversion and addressed to the Department of the Navy has been referred to the Bureau of Ships for action.

Distilled water may be produced from sea water by one of two general methods, namely: ion exchange and distillation. The former method is entirely too expensive to justify further consideration. Other methods such as solar radiation, ultra-high frequency, etc., have been considered, but it has been finally concluded that at this time the distillation of sea water constitutes the only practical and feasible method for large-scale sea-water conversion.

The United States Navy has for over 40 years been manufacturing its own fresh water aboard naval vessels by the distillation of sea water. This water is used for drinking, washing, and cooking purposes, and for boiler feed and storage battery make-up among other usages. Shipboard distillation is accomplished either by low-pressure (vacuum) steam or vapor (thermal) compression distilling plants. In general, Diesel-driven vessels are equipped with Badger (Kleinschmidt) motor-driven vapor compression distilling plants, initially developed by the Bureau of Ships (Engineering) in 1937, of either 1,000 or 2,000 g. p. d. (gallons per day) capacity, whereas large steam-turbine-driven vessels are equipped with two or more multieffect low-pressure (vacuum) steam distilling plants ranging in capacities from 4,000, 8,000, 12,000, and 20,000 g. p. d. double effect to 20,000, 30,000, and 40,000 g. p. d. triple effect distilling plants. The low-pressure steam units normally utilize auxiliary exhaust steam, the latent heat of which would otherwise be discharged overboard via the main and/or auxiliary condensers.

The installation of multiple-effect units results in substantial increases in distilled-water yield per input unit of heat energy. The heat energy required to produce 1 pound of water for various types of distilling units is indicated as follows:

	B. t. u. per lb.
Single effect, low-pressure steam	1,040
Double effect, low-pressure steam	565
Triple effect, low-pressure steam	370
Vapor compression plant (⅛ blow-down)	69

On the basis that no surplus auxiliary exhaust steam is available, 1 pound of fuel oil will normally yield from 30 to 35 pounds of fresh water for a triple-effect plant and from 21 to 25 for a double-effect plant. However in the case of a steam plant employing bleed steam from a turbine as the heating medium after the steam has performed work in generating power, it is estimated that the economy of a double-effect plant based on an initial steam turbine condition of 415 pounds per square inch and 700° F. (TT) will be 70 pounds of fresh water per pound of fuel oi for a bleed point pressure of 5.0 pounds per square inch. At riple-effect plant willl result in yields approximately 50 percent greater. In the case of a Diesel-engine-driven vapor compression plant a fuel economy of from 150 to 165 pounds of water per pound of fuel, equivalent to 55 cents per 1,000 gallons, is attained.

In order to realize the maximum economy possible, it may prove advantageous to combine a noncondensing turbine driven vapor compression distilling unit with a multiple effect low-pressure (vacuum) steam distilling plant operated by the exhaust steam of the turbine. Superimposed on top of this combination would be a solar energy heat exchanger which coupled with the high vacuum multiple-effect, flash-type distilling plant could yield large volumes of fresh water at minimum cost.

In case you desire further detailed information on Navy-type distilling plants, the following chapters of the Bureau of Ships Manual can be obtained from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. at a nominal price:

Chapter 58 (sec. I)—Low pressure steam distilling plants.
Chapter 58 (sec. II)—Vapor compression distilling plants.

As regards distillation costs for various types of plants it is suggested you contact the Badger Manufacturing Co. (Mr. John J. Campobasso) and/or Arthur D. Little Inc. (Mr. Allen Latham), both of Cambridge, Mass., for vapor (thermal) compression distilling plants and the Griscom-Russell Co. (Mr. Sifrain F. Maury) of 285 Madison Avenue, New York City, for low pressure (vacuum) steam multi-effect distilling plants of both the submerged tube and flash types.

Sincerely yours,

WEEI, Columbia Broadcasting System, Inc.,
Boston 12, Mass.

(Attention Mr. J. H. Duffum.)

Gentlemen: The Department of the Navy acknowledges receipt of your letter of March 15, 1950, requesting information on the conversion of sea water into fresh water on a large scale for agricultural purposes.

Distilled water may be produced from sea water by means of one of two general methods, namely, ion exchange and distillation. The former method, which employs base exchange zeolites or synthetic resins, is widely used in producing softened or distilled water from fresh water but would be far too costly in removing

the tremendous quantities of salts occurring in sea water. The most efficient ion exchangers available today cannot practically demineralize water containing more than 1,000 parts per million of total solids. The treatment of sea water containing roughly 40,000 parts per million of dissolved salts by the ion exchange method would entail an expenditure of approximately $20 for every 1,000 gallons of fresh water produced. Other methods such as solar radiation, ultra-high frequency, etc., have been considered, but it has been finally concluded that the distillation of sea water constitutes the only practical and feasible method for large-scale sea-water conversion.

The United States Navy has for over 40 years been manufacturing its own fresh water aboard naval vessels by the distillation of sea water. This water is used for drinking, washing, and cooking purposes and for boiler feed and storage battery make-up among other usages. Shipboard distillation is accomplished either by low-pressure steam or vapor (thermal) compression distilling plants. In general, Diesel-driven vessels are equipped with Badger (Kleinschmidt) motor-driven vapor compression distilling plants, initially developed by the Navy in 1937, of either 1,000 or 2,000 g. p. d. (gallons per day) capacity whereas large steam turbine driven vessels are equipped with two or more multieffect low pressure (vacuum) steam distilling plants ranging in capacities from 4,000, 8,000, 12,000, and 20,000 g. p. d., double effect to 20,000, 30,000, and 40,000 g. p. d. triple effect distilling plants. The low pressure steam units normally utilize auxiliary exhaust steam, the latent heat of which would otherwise be discharged overboard via the main and/or auxiliary condenser(s). The installation of multiple effect units results in substantial increases in distilled water yield per input unit of heat energy. The heat energy required to produce 1 pound of water for various types of distilling units is indicated as follows:

	B. t. u. per pound
Single effect plant, low-pressure steam	1,040
Double effect plant, low-pressure steam	565
Triple effect plant, low-pressure steam	370
Vapor compression plant	69

On the basis that no surplus auxiliary exhaust steam is available, 1 pound of fuel oil will normally yield from 30 to 35 pounds of fresh water for a triple effect plant and from 21 to 25 for a double effect plant. However, in the case of a steam plant employing bleed steam from a turbine as the heating medium after the steam has performed work in generating power, it is estimated that the economy of a double effect plant based on an initial steam turbine condition of 415 pounds per square inch and 700° F. will be 70 pounds of fresh water per pound of fuel oil for a bleed point pressure of 5 pounds per square inch. A triple effect plant will result in yields approximately 50 percent greater. In the case of a gasoline-engine-driven vapor compression plant a fuel economy of from 150 to 165 pounds of water per pound of fuel, equivalent to 55 cents per 1,000 gallons, is attained.

In order to realize the maximum economy possible, it may prove advantageous to combine a noncondensing turbine-driven vapor compression distilling unit with a multiple-effect low-pressure (vacuum) steam distilling plant operated by the turbine exhaust steam. Superimposed on top of this combination plant, would be a solar energy heat exchanger which coupled with high vacuum multiple effect distillation could yield large volumes of fresh water at minimum cost.

Considerable governmental interest has been directed to the economical conversion of sea water to fresh water and public hearings on Senate bill 1300 introduced by Senator O'Mahoney, will take place in the near future. The Department of the Interior has been requested to take the lead on behalf of the administration in recommending early enactment by the Congress of legislation authorizing necessary research, experimentation, and demonstration designed to develop economic means of producing from sea water, water which is suitable for agricultural, industrial, municipal water supply, and other beneficial consumptive uses. It is suggested that you obtain a copy of this bill as possible interest to your inquiry from the West Indies.

In case you desire further detailed information on Navy type distilling plants the following chapters of the Bureau of Ships Manual can be obtained from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., at a nominal price.

Chapter 58 (sec. I), low pressure steam distilling plants.
Chapter 58 (sec. II), vapor compression distilling plants.

As regards distillation costs for various types of plants it is suggested you contact Badger Manufacturing Co. (Mr. John J. Campobasso) and/or Arthur

D. Little, Inc. (Mr. Allen Latham) both of Cambridge, Mass., for vapor (thermal) compression distilling plants and the Griscom-Russell Co. (Mr. S. F. Maury) of 285 Madison Avenue, New York City, for low-pressure (vacuum) steam multi-effect distilling plants.

Sincerely yours,

———— ————.

The UNIVERSITY OF WYOMING,
College of Engineering, Laramie, Wyo.
(Attention Mr. John M. Hill.)

GENTLEMEN: The Department of the Navy acknowledges receipt of your letter of April 13, 1950, requesting information on the Navy's practice of distilling sea water in large quantities.

The United States Navy has for over 40 years been manufacturing its own fresh water aboard naval vessels by the distillation of sea water. This water is used for drinking, washing, and cooking purposes, boiler feed, and storage-battery make-up, etc. Distillation aboard naval vessels is accomplished either by low-pressure steam or vapor compression (motor driven) distilling plants. In general, Diesel-driven vessels are equipped with Badger (Kleinschmidt) motor-driven vapor compression distilling plants, initially developed by the Navy in 1937, of either 1,000- or 2,000-gallons-per-day capacity whereas large steam-turbine-driven vessels are equipped with two or more multieffect (double or triple) low-pressure (vacuum) steam distilling plants ranging in capacities from 4,000, 8,000, 12,000, and 20,000 gallons per day double effect to 20,000, 30,000, and 40,000 gallons per day triple effect units. The low-pressure steam distilling plants normally utilize auxiliary exhaust steam, the heat of which would otherwise be discharged overboard via the main and/or auxiliary condenser(s). The installation of multiple-effect units results in substantial increases in distilled water yield per input unit of heat energy which still comes far from approaching the yield obtained with a vapor compression unit. The heat energy required to produce 1 pound of water for various types of distilling units is indicated as follows:

	B. t. u. per lb.
Single effect plant, low-pressure steam	1,040
Double effect plant, low-pressure steam	565
Triple effect plant, low-pressure steam	370
Vapor compression plant (⅓ blow down)	69

In order to realize the maximum economy possible, it may prove advantageous to combine a noncondensing turbine-driven vapor compression distilling unit with a multiple-effect low-pressure steam distilling unit operated by the turbine exhaust steam. Superimposed on top of this combination plant, would be a solar energy heat exchanger which coupled with high-vacuum multiple-effect distillation could produce large volumes of fresh water from sea water at minimum expense. A similar combination would consist of a Diesel-driven vapor compression plant wherein the heat in the Diesel-engine jacket water and/or exhaust gas could also be employed for distillation purposes.

In case you desire any further detailed information on distilling plants the following chapters of the Bureau of Ships Manual can be obtained from the United States Government Printing Office (Superintendent of Documents) Washington 25, D. C. at a nominal price:—

Chapter 58 (sec. I), Low-pressure steam distilling plants.
Chapter 58 (sec. II), Vapor compression distilling plants.

As regards distillation costs for various types of plants it is suggested you contact Badger Manufacturing Co. (Mr. John J. Campobasso) and/or Arthur D. Little Inc. (Mr. Allen Latham) both of Cambridge, Mass. for vapor (thermal) compression distilling plants and the Griscom-Russell Co. (Mr. S. F. Maury) of 285 Madison Avenue, New York City, for low pressure (vacuum) steam multi-effect distilling plants.

Sincerely yours,

———— ————.

Senator ANDERSON. From the State of Washington, mention is made of the fact that farmers living in the Roza project feel that if the rain-making activities continue that they are going to lose their crops. They have organized two or three of what they call defensive

organizations for farmers of the Pasco pumping project, the Central Washington Protective Association, Roza Water Users Property Improvement Association, and the Washington Horticultural Association.

Now, we have had during the hearings a number of observers. If any of the observers desire to announce who they are and their interest in this, we would be glad to have their names. I know the Defense Establishment has a person or two here, and if any of you people desire to identify yourselves, I would be happy to have that identification for the record.

Major WICKHAM. I am Maj. John A. Wickham, representing the Department of Defense, Army Office of Legislative Liaison.

Mr. CROWLEY. Mr. Chairman, I would like to have the record show, if I may, that an observer from the Civil Aeronautics Board has attended all of these hearings and will continue to do so until they are finished. My name is Harold G. Crowley, Civil Aeronautics Board.

Senator ANDERSON. Let me say if at any time you want to make a statement or add anything to the discussion, we know that Civil Aeronautics has had a great deal of experience in this field, and would be very happy to have your comments and suggestions at any time.

Mr. CROWLEY. Thank you very much.

Mr. LANDSBERG. Dr. H. E. Landsberg, Research and Development Board.

(A statement on Weather Modification and Control, subsequently received from the American Meteorological Society, appears in the appendix. See p. 318.)

Senator ANDERSON. I think I will ask permission at this time to file in the record a letter of mine of March 17 to the Secretary of the National Weather Improvement Association, trying to review the long effort that I have made to get comments and statements from stockmen's organizations and ranchers, to make absolutely sure that everyone has had an opportunity to be heard.

(The letter above referred to is as follows:)

MARCH 17, 1951.

Mr. JIM WILSON,
Secretary, National Weather Improvement Association,
Fort Collins, Colo.

DEAR MR. WILSON: As you know, I have been disturbed by statements in the releases of the National Weather Improvement Association concerning me and the purposes of my bill, S. 222, on weather control. By correspondence with you I learn that your members are afraid of my bill because of the feeling that I have been unwilling to take them into my confidence and let them know what I have been doing or ask their opinions on provisions that will affect them.

Nothing could be further from the truth. If ever a bill was drawn after long consultation with every group that expressed any interest whatsoever in the subject, it was S. 222.

To begin with, we started work in September 1950. We began going through all sorts of background material including the hearings which had been held in 1948. The association of land-grant colleges had gone on record as favoring an experimental rain-making program and by the middle of October my office was endeavoring to work out language for a bill.

My attention, of course, had been called to the fact that New York City was trying to relieve its scarce water supply by cloud seeding. I had observed that temperatures in the West were gradually rising and it seemed certain that we could look for continued dry spells and a reduction in the amount of water in the reservoirs behind our irrigation projects. On October 31 there was an informal meeting of Federal agencies, arranged by my office, attended by representatives of the Commerce Department, Weather Bureau, Civil Aeronautics Board, United

States Air Force and the Signal Corps plus the legislative counsel of the Senate. That meeting brought out the fact that there was a vast area of disagreement between people like Langmuir and Workman on the one side, and the Weather Bureau and the Signal Corps on the other. The proposal was made that two drafts of the bill be prepared for study. That was done and a great deal of advice and information was received from groups which had expressed an interest. I regret to say that your organization was either not in existence or had not expressed any interest in the matter that we knew of. News stories were carried Nationwide that a group was at work on a bill and many inquiries came in to us.

Eventually I chose between the two drafts submitted and prepared a bill for introduction. That bill was S. 4236 introduced on December 8, 1950. It was not buried but on the contrary I presented a statement which covered more than two pages of the Congressional Record discussing the provisions of the bill. As soon as printed copies were available they were mailed to every organization and every individual who had expressed the faintest interest in the idea.

At the time I introduced the bill I told interested parties, such as the Meteorolgical Society and others, that I had no intention of following it up at that session.

To show you how I tried to make sure that this bill was discussed, let me take the case of your vice president, Albert Mitchell. He was, in my opinion, the most active person in the promotion of rain making in my home State and I want you to see what I did in his case. I talked to him in New Mexico and told him of my plans to introduce a bill. He asked that when a copy of the bill was ready, one be sent to him so that he could study it. In the memorandum which I mailed to my office in Washington from my office in Albuquerque I said that Mr. Mitchell was very much worried that the bill would make it difficult for experimental work to be done and I pointed out that the stockmen had benefited greatly by what they've had a chance to do thus far and that we wanted to see that they had a chance to do still more in the future.

On November 9, 1950, by air mail a copy of the latest draft of the contemplated bill was sent to Mr. Mitchell with a statement that the draft was developed to serve as a working basis and to get the reaction of officials from various Government agencies concerned. Mr. Mitchell was advised that I intended to introduce the bill when the Congress reconvened in November and it was suggested to him that he talk to us before that time and return the enclosed draft.

Mr. Mitchell replied on November 15 expressing his thanks for a chance to look over the legislation and announcing that he would return it as soon as possible.

On November 26 he sent me the copies of the proposed bill from New York and said that he had been going over it with Colonel Gillenwaters of the Krick organization and that he (Colonel Gillenwaters) had made some notes which he was forwarding for my information. That memorandum by Mr. Gillenwaters is still in my files. It is dated November 20, 1950, and was considered carefully by me before the bill was presented.

Mr. Mitchell told me in that letter that Dr. Krick had advised that he would like to discuss the legislation with me on December 7. I withheld introduction of it until they could reach Washington. They came to my office that time and copies of the bill as it stood were given to both of them. They expressed an interest to be kept informed on developments of the bill, said they felt that we should make sure that the pioneering scientists in the field, as Dr. Krick regarded himself, was not to be curtailed in his operations, to which I agreed and we left, I thought, with everyone on an amiable basis. To say subsequently that I have tried to introduce it without taking people into my confidence, without letting them know what I was doing, and without asking them their opinion upon the provisions that affected them is sheer nonsense. I did just the reverse with every agency or organization that I knew had any interest in the bill whatever. I have irrefutable proof of that in my office.

Now a word as to my present intentions. I have no desire or intention to try to shove a bill of this nature through the Congress without giving everyone an opportunity to be heard and to confer on the provisions of the bill. Every step I have taken has been with the sole thought of giving every party an opportunity for fullest consideration and discussion. If the National Weather Improvement Association wants to be heard by the committee, we will reopen hearings and give it a chance to be heard. I have already wired the president of your organization to that effect. If there are points in the bill which they think should be changed, we would like to have the suggested language that the members of your association would like to see substituted in order that we may consider it. If they feel that the whole scope of the bill is too broad and that the alternative proposal with

which the informal groups meeting in my office worked for several weeks would be better, then that might be suggested to the committees and studied by those Members of the Senate particularly interested in it.

If your members have come to believe that this bill was drafted without an "aye," "yes," or "no" to them, then they should have the truth and my files will show them the truth.

I want to make it clear as crystal that I would not approve and do not intend to support legislation that would try to keep ranchers and farmers from having their private rain makers. I think that the Federal Government should be spending money in that field for experimental work but if any group of ranchers wants to hire a private rain maker, I have no objection whatever and do not intend to try to interfere with that activity in the slightest. I do say that there's an analogy in the early history of aviation in this country. People objected to the establishment of the Civil Aeronautics Administration. Many people contended that the air should be free and that States might regulate the landings at individual airports but that the sky belonged to all of us and anyone should fly through it as he wished. To use an illustration that I have used before, Capt. Eddie Rickenbacker wanted to fly a few passengers along the eastern seaboard. He had absolute freedom. He could go anywhere he wished. He could land in any cornfield or any highway or on any airport. He had absolute freedom—to starve—and that's what he did until Federal regulation was brought into being by the establishment of the Civil Aeronautics Administration. Then he must fly his ships in an established pattern. Then he must use airplanes that had been checked and the design approved by engineers of the Civil Aeronautics Board. The men who flew those planes had to be licensed. All that regulation came in but it made Eastern Airlines a great industry.

We must contemplate something of that nature in rain making or we will lose what I think is the greatest opportunity we now know to guarantee the prosperity and agricultural productiveness of the arid West. We must have a licensing system so that we know where people are going and what they are doing in order that over-all results may be studied and evaluated by scientists all over this Nation. We must be sure that the men who plan the programs are trained meteorologists. Dr. Krick would benefit most of all by such regulation because he is preeminent in the field and might have virtually a monopoly for many years to come. That doesn't worry me in the slightest. I do recall, however, that at a meeting at the school of mines in New Mexico some years ago there was general understanding that professional rain makers would report what they were doing. There is no agency now to which any of them are reporting. If they may fill the skies with silver iodide and private farmers, ranchers, and enthusiasts may do the same thing with ample generators, then I submit to you that no one will know whether rain has or has not been produced. There are scientists who believe it is impossible to produce rain. I do not agree with them. I have no scientific knowledge upon which to base my disagreement and, therefore, I want the widest possible experimentation to continue but I want it so reported and registered and licensed that when it is over we will be able to gain some knowledge from a study of what has been done.

Those people who improperly claim that my only desire is to set up a Federal bureaucracy must overlook the fact that when I became Secretary of Agriculture I reorganized its operations and discharged 20,000 of its employees. Let that one fact stand against the claims of my accusers.

I think that the National Weather Improvement Association would best serve its purposes by trying to come in and help us draft decent legislation. From the very first day that I determined to draft a bill I have been holding that door open. It is still open and I hope the National Weather Improvement Association will accept the invitation.

Sincerely yours,

CLINTON P. ANDERSON.

Senator ANDERSON. We will start, then, with Mr. Eardley, of the Department of Justice.

STATEMENT OF CARL EARDLEY, ATTORNEY, CLAIMS DIVISION, DEPARTMENT OF JUSTICE

Mr. EARDLEY. Mr. Chairman and members of the committee, I am going to talk very briefly this morning, probably about the least

interesting part of these bills, and that relates to the liability which the Government is apparently intending to assume by reason of the proposed rain-making activities, and to make certain comments with respect to the various bills and certain suggestions.

Senator ANDERSON. Not being a lawyer, I am not going to try to correct your terminology. I do not think the Government is planning to assume liabilities as much as the idea that if suits are to be filed they would have to be filed against the Government instead of against the contractor who is carrying out the Government's request.

Mr. EARDLEY. Yes, sir. Well, I will go into that a little.

First, since I understand you are not all lawyers, I would like to make briefly a statement as to what the liability of the United States is now with respect to negligent acts. Of course, you are aware that the United States for a long time has been liable for breeches of contract and has also been liable under the Constitution for deprivation of property without due process, but it was not until quite recently that the Government assumed responsibility for the negligent acts of its officers and employees. That was done in the Federal Tort Claims Act.

However, there was one reservation to that general assumption of liability, and that was with respect to discretionary acts. We are at the present not liable for discretionary acts.

For example, in a recent case the Army engineers through a contractor undertook to do some work in the Missouri River building dikes, and so forth, which caused consequential damage to one of the riparian owners. The Supreme Court held that that work in the river was a discretionary act and for that neither the contractor nor the Government would be liable.

There is an area of doubt now, and that is the question of whether or not the Government is liable for negligence in the performance of discretionary acts. As you may recall, there was a tremendous disaster at Texas City sometime ago and that question is now before the courts. It has not been resolved, and I believe that in this proposed legislation, for the purpose of this legislation, at any rate, it should be resolved.

I mean, the Congress should decide whether it intends that the Government assume responsibility for negligence in the performance of what will be a discretionary act.

Senator CORDON. Is the same situation true in Oregon in connection with the floods of the Columbia River and losses of the city of Vanport?

Mr. EARDLEY. I am not familiar, sir, with that.

Senator CORDON. You had better familiarize yourself with it. There are a flock of damage suits pending.

Senator CASE. Has it not been customary in the claims bills, which the Congress passed prior to the Federal Torts Act, to recognize responsibility for negligence on the part of Government employees, and if so has that not been the performance of discretionary acts?

Mr. EARDLEY. Well, no. For example; a postman (most of these suits arise from automobile accidents and so forth). Those are administrative acts, and in the performance of those administrative duties, if the agents are negligent, the Government is liable.

Senator CASE. I served on the Claims Committee in the House at one time, and I recall that we had a great many bills to do with accidents involving the operation of trucks by persons in the Civilian Conservation Corps.

Senator CORDON. No legal liability there at all, however. That was the reason you had them in the Congress.

Senator CASE. There was no legal liability.

Mr. EARDLEY. Were those private acts?

Senator CASE. Those were private acts, but they recognized the responsibility on the part of the Government, and, of course, at that time the Government could not be sued without its consent. The Federal Torts Act changed that.

Mr. EARDLEY. That is now changed. There is a big argument as to how it was changed with respect to the negligence in performance of discretionary acts. We have taken one position in the Texas City suits.

Senator CASE. Under the Federal Torts Act have you not received and accepted suits where accidents took place comparable to the injuries sustained by people when trucks were operated by drivers for the CCC?

Mr. EARDLEY. I do not quite see the purport of your question.

Senator CASE. I thought under the Federal Torts Act that you had been accepting Government liability and permitting Departments to settle claims under $1,000 where the injury was the result of something comparable to the accidents when drivers of trucks for the Civilian Conservation Corps hit someone.

Mr. EARDLEY. I do not know what the agencies have been doing. It is completely out of my field. I do know that the Department has taken the position that under the Tort Claims Act the Government is not liable for negligence because of the wording of the act.

Senator CASE. Claims are being settled up to $1,000 by the Department's directive, are they not?

Mr. EARDLEY. Yes, sir, but I do not know whether those claims involve an act of negligence in the performance of a discretionary duty.

Senator CASE. The construction work that was carried on by the Civilian Conservation Corps or the WPA, that was not an administrative function, was it?

Mr. EARDLEY. Well, I do not know——

Senator CORDON. The difference between the two is whether there is negligence there, is it not?

Mr. EARDLEY. Well, we are responsible for certain acts of negligence.

Senator CORDON. Take your discretionary duty case and assuming someone goes ahead with something he has determined, after a consideration of the matter, should be done in the public interest, that is discretionary?

Mr. EARDLEY. That is discretionary.

Senator CORDON. And in the course of that act there is negligence in the performance of it. Is it your view that the Government has no liability there?

Mr. EARDLEY. Sir, I do not care to express my view.

Senator CORDON. All right, the view of the Department.

Mr. EARDLEY. The view of the Department of Justice is the Government has no liability.

Senator CORDON. Let me bring it down to a practical case; in the case of the engineers building an obstruction in the Missouri River, say the Government has a truck driver or perhaps a passenger car

driver taking engineers down to the spot where they are working on a public highway, and through his negligence there is damage; is it the Department's view that there is no liability there because at the far end there was some discretionary action?

Mr. EARDLEY. On that specific example I do not care to hazard a guess as to what the Department's view would be.

Senator ANDERSON. You can understand why those of us who are not lawyers would not hazard a guess either.

Mr. EARDLEY. In the most recent case to be decided, that question came up, and the court itself said that it did not care to try to decide that question. It is a close question.

Senator CORDON. Your chief statement this morning, then, is that the Government, itself, does not know what its liability is in that field.

Mr. EARDLEY. There is no question but that there are valid arguments on both sides. My only thought is that if you have definite views, that if the Congress has definite views, they should be expressed in the legislation so that any area of doubt will be removed insofar as this bill is concerned.

Senator CORDON. That is a sound approach.

Senator ANDERSON. What do you think the language of this bill intends to do, S. 222?

Mr. EARDLEY. I have three bills.

Senator ANDERSON. Yes. All right, go ahead. There would be no legal complications?

Mr. EARDLEY. S. 798 leaves the law as it is.

Senator ANDERSON. And S. 5 leaves the law as it is, does it not?

Mr. EARDLEY. S. 5 provides in section 5 that "The acts and omissions of any person or corporation," and so forth, are "deemed the acts and omissions of the United States." That does not change the law. A contractor who now works for the Government in the performance of a discretionary act would not be liable to damages.

Senator ANDERSON. I said S. 5 leaves the law as it is. Is that a correct statement?

Mr. EARDLEY. As you go into it a little more, it provides that the Secretary of the Interior is authorized to provide in any such contract that "The United States shall indemnify the contractor against liability on account of claims," and so forth.

I can foresee an argument by attorneys representing injured parties to the effect that this was intended to be a waiver of immunity, that Congress intended to recognize the rights of injured parties to recover.

Senator ANDERSON. You can always see the possibility of a legal argument. What is the law?

Mr. EARDLEY. I mean with respect to this provision. Again I say until the thing is decided by the court, my personal view, if that is of any interest to you, is I do not believe that that changes the law, but I believe that it should be made specific. There is no intent to change the liability of the Government, that it does not intend to waive immunities.

Senator ANDERSON. Can you submit language that does make it specific?

Mr. EARDLEY. Yes, sir; if we were requested to do so.

Senator ANDERSON. I hereby request you to do so.

Mr. EARDLEY. Not at this moment.

Senator ANDERSON. I know it. I do not want it that rapidly. I want the language studied.

Mr. EARDLEY. We have not been requested to propose amendments to the bill, but will be glad to do so.

Senator ANDERSON. Mr. Astin, will you see that the Department of Justice is asked to propose language to cover what points it may have in S. 5?

Senator CORDON. And a comment upon the advisability of any assumption of further responsibility.

(Amendatory language for sec. 5 of S. 5 was subsequently submitted by the Department of Justice as follows:)

DEPARTMENT OF JUSTICE,
OFFICE OF THE DEPUTY ATTORNEY GENERAL,
Washington, May 23, 1951.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

MY DEAR SENATOR: This is in response to your request for the submission by the Department of Justice of specific language amending section 5 of the bill, (S. 5) to provide for research into and demonstration of practical means for the economical production, from sea or other saline waters, or from the atmosphere (including cloud formations), of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses, and for other purposes. The request was originally made of Mr. Carl Eardley of this Department at a hearing on March 19, 1951, before subcommittees of the Committees on Interior and Insular Affairs, Interstate and Foreign Commerce, and Agriculture and Forestry on S. 5, and the related bills, S. 222 and S. 798. The request was confirmed by letter of April 19, 1951, from Mr. Mills Astin, chief clerk, of your committee.

One of the main purposes of the bill is to promote research in the field of artificial inducement of precipitation from cloud formations. To this end it would authorize the Secretary of the Interior to enter into research contracts with private persons and organizations. In order to make such contracts more attractive to such persons and organizations, section 5 of the bill, as it now stands, would provide as follows:

"SEC. 5. The acts and omissions of any person or corporation who, in accordance with the terms of a contract with the United States entered into under the provisions of this Act, carries on operations for the artificial inducement of precipitation shall, with respect to third parties who are or may be adversely affected by precipitation so induced or by other meteorological phenomena caused by such inducement or attempts thereat, be deemed the facts and omissions of the United States and shall be governed by the law applicable to the same, and the Secretary of the Interior is hereby authorized to provide in any such contract that the United States shall indemnify the contractor against liability on account of claims (including reasonable expenses of litigation and, when approved in advance by the Secretary, compromise or settlement of such claims) made by third parties as hereinbefore described and any contract so providing shall also contain appropriate provisions for notice to the Government of suits or actions filed, or claims made, against the contractor with respect to any alleged liability to which the indemnification provisions relate and for control of or assistance in the defense of any such suit, action, or claim by the Government at its election."

It appears to be the purpose of section 5 to immunize contractors from liability for injuries to third party private interests which allegedly result from the performance of the Government's work even though due to acts involving exercise of discretion by the contractor, but that they are not intended to be specially protected where the injuries result from the contractors' normally actionable acts of negligence which occur in the course of performance. For example, the contractor would not have to pay for the damages resulting from a flood found to have been caused by seeding a cloud in accordance with Government directions even though the time and place of the seeding might have been determined by the contractor, but he would be liable for a collision between his airplane and another, that occurred during the course of the seeding, if found to have been due to his

negligence. Although it now appears to be the rule that Government contractors are not liable for injuries necessarily resulting from the performance of the Government's work (*Yearsley* v. *Ross Construction Co.*, 309 U. S. 18, 20–21), there is no decision to that effect where the contractor was given discretion as to choice of place or method and the injury allegedly resulted from such choice. At the hearing Mr. Eardley, in effect, suggested that section 5 might be construed both to enlarge the liability of the United States to include torts by the contractor, for which it would not now be liable, and to relieve the contractor of liability for torts for which he would be solely responsible under existing law. Since it seems to be intended that such immunization of contractors shall not result in greater Government liability than is necessary for that purpose, the following language is suggested:

"No person or corporation who, in accordance with the terms of a contract with the United States entered into under the provisions of this Act, carries on operations for the artificial inducement of precipitation shall, with respect to third parties, who are or may be adversely affected by precipitation so induced, or by other meteorological phenomena caused by such inducement or attempts thereat, be held liable in money damages to such third parties by reason thereof, and no suit shall be maintained by any such third party against the United States on account of the activities of any such person or corporation in connection with the performance of such a contract: Provided, however, that if, by the Constitution of the United States, just compensation is required to be paid by reason or as a result of such operations or the provisions of this Act, a claim for the same may be entertained by the Court of Claims only under section 1491 of title 28, United States Code. Nothing herein shall be construed as an interpretation of the Constitution which would impose any liability on the United States by reason of such activities or of the terms of this Act. For the purpose of enforcing the provisions of this section, any action within the reach of the judicial power of the United States, that is pending in any State court of original jurisdiction may be removed at any time to the district court of the United States of the judicial district wherein such State court is located, in the same manner as actions are removed pursuant to section 1441 of title 28, United States Code, regardless of any lack of jurisdiction of the district court that might otherwise exist."

It is believed that this suggested language will serve to immunize the contractors and the United States from liability for injuries from rain-making experimentation to the fullest extent possible under the Federal Constitution.

Mr. Astin's letter also requests that language be drafted "to define the discretion which might be exercised by an operator engaged in silver iodide experimentation." Mr. Eardley does not recall having discussed this subject and no reference to it is found in the transcript of the hearing. The Department would be unable to comment on this matter without a detailed explanation of the problem.

This letter is limited to the submission of amendatory language for section 5 of S. 5 and should not be construed as expressing approval or disapproval of any other provision of the bill, or of the bill itself.

Yours sincerely,

PEYTON FORD, *Deputy Attorney General.*

Senator CASE. Is it the view of the witness that the language he cited accepts for the Government the liabilities that might be created by the operations of the contractor?

Mr. EARDLEY. Yes.

Senator CASE. That is contrary to what is generally done in public works projects. You referred to the Missouri Basin program. Now, I recall distinctly that within the past 2 years there were some boys who lost their lives when a flash flood tore some works on the Angostura project which was being constructed by the Bureau of Reclamation in the Missouri River program, but it was not being constructed by Government directive. It was a contract operation. The contractor was under bond, according to my memory, so that he had a bondsman to take over the liability. Is it your fear that this language here would accept for the Government the responsibility?

Mr. EARDLEY. It provides that—

the Secretary of the Interior is authorized to provide in a contract—

Of course, that does not mean that he is going to—

that the United States shall indemnify the contractor against liability on account of claims—

but it seems to me that the ostensible object here is to take care of the contractor so that, in this work about which there is considerable speculation as to results, he will not be injured financially in undertaking work for the Government.

Senator CASE. It occurs to me that there are two areas. One would be negligence, and the other would be for the performance of the act itself. That is, if the Federal Government went into the business of experimenting in weather control, the Government might—properly, in my judgment—accept some responsibility for the modification of weather resulting if damages grew out of that as such, or at least relieve the contractor of liability and preserve the Government's protection against suits. But the Government, in my judgment, ought not to accept responsibility for negligence on the part of the contractor in carrying out a contract.

Mr. EARDLEY. Well, you see here the terms of the contracts are not specified, and it seems to me that the Secretary of the Interior would very likely provide in the contract that the Government would not assume liability for the contractors' negligence. This gives considerable authority to the Secretary of the Interior.

Senator ANDERSON. It is not contemplated that they shall assume liability for negligence. The difficulty is that if somebody is seeding clouds out in Arizona or Colorado or Wyoming, and there is a series of rainfalls that sweep the Ohio River Valley, and a large and well-financed corporation is doing the seeding, there usually follows, or sometimes might follow, suits against that corporation, and the corporations in the past have been known to settle on a nuisance basis, not necessarily because of the question of liability but just in order to prevent harassment in the courts.

The legislation is designed to say that if the contractor is carrying out a specific experiment at the behest of the United States Government—if someone feels that the precipitation induced has rained out his baseball game or his football game, that he shall sue the Government instead of suing the contractor who happened to be flying a ship, maybe, on the western slope of Oregon, testing out the theory that Dr. Schaefer had the other day—that you could lift some of those clouds over to the other side of Oregon in trying to get artificial precipitation of water. I do not believe that would be negligence on the part of the contractor; would it?

Mr. EARDLEY. I do not think so. I have only listened to 1 day of the hearings, but it seems to me that one of the problems here would be to determine where negligence existed. In other words, the art is apparently in such a stage, it would be difficult ever to prove that there was negligence, because no one can forecast yet with certainty what the result would be; so there would not be any basis of determining negligence.

Senator CORDON. I think you had better give a little consideration to the first part of section 5 if you are going to discuss that, because you will note there that it is—

The acts and omissions of any person or corporation who, in accordance with the terms of a contract, carries on operations—

if he is carrying it on in accordance with the terms of a contract, he is not negligent.

Senator CASE. What page is that?

Senator CORDON. That is on page 5. Not pursuant to a contract, but in accordance with the terms of it.

Senator CASE. That is in S. 5 rather than in S. 222?

Senator ANDERSON. He read from S. 5.

Mr. EARDLEY. But there can be negligence in the performance of the terms of the contract, and it should be settled as to what the congressional intent is with respect to——

Senator CORDON. Not if you perform it in accordance with its terms.

Senator ANDERSON. It strikes me that if he has done what the contract calls for, how does he become negligent?

Mr. EARDLEY. Well, the contract might call for the construction of a building and one might do a first-class job, and turn it over just exactly as the specifications called for, but he might injure somebody negligently while constructing the building. He has performed the terms of the contract, but he has been guilty of a tort in the performance.

Senator ANDERSON. He is required to carry insurance for that and does carry insurance for that. This is a wholly different question.

Mr. EARDLEY. Well, I notice that in S. 222 you provide for compensation for those who are not compensated by insurance. That is one of the provisions. I do not know whether the insurance companies have been represented here or not.

Senator CORDON. The only damage that is contemplated here is that which results from the action in the field of meteorology. No other negligence is involved. The damage must be the result of artificial inducement of precipitation. "The parties who may be adversely affected by precipitation or other meteorological phenomena"—that is the extent of the application of the section, so your ordinary negligence is not applicable. Assume that you are going to contract for a man to do certain things and that you are going to set out what he is to do in that field. This provision does not go beyond that. If his airplane crashes and creates damage it has nothing to do with this.

Mr. EARDLEY. The performance of the acts contemplated here in rain making would be discretionary acts. However, there could be, I presume, in the performance, and inasmuch as there is considerable doubt now as to the liability——

Senator ANDERSON. How? You take a generator and set it out on the mountainside and start the fire under it to set off a little stream of silver iodide, tiny particles, going up into the air. How would you get your negligence from that?

Mr. EARDLEY. As I pointed out before, that is one of the problems connected with this. We do not have any standards upon which we gage negligence or nonnegligence, because we cannot forecast what the reasonable result is going to be of the particular act, so it will be very difficult for anyone to prove that an individual engaged in this type of work is negligent at this particular time, but some day you may know precisely what will happen when you put so many pounds or tons, or

whatever it is, into a certain cloud formation. A man skilled in the art can probably forecast it.

Senator ANDERSON. Let me see if I can get at it another way. What is it that you are trying to advise us to do this morning? The Department of Justice is the legal adviser to the departments of the Government.

Mr. EARDLEY. Yes, sir.

Senator ANDERSON. You are going to make it definite as to discretion. You are going to submit language on that?

Mr. EARDLEY. Yes, sir.

Senator ANDERSON. What else do you recommend to us?

Mr. EARDLEY. I have nothing else to recommend except we believe that in view of the state of the art it might be better now to reserve complete immunity from that sort of damage.

Senator ANDERSON. What do you mean by "complete immunity"?

Mr. EARDLEY. So that the Government would not be liable under any circumstances for rain-making activities, because we do not know what is going to happen. You might have billions of dollars of claims which flood the courts, and until there is some understanding of what the possibilities are it might be better to go more slowly.

Senator ANDERSON. That is precisely what the difficulty is. You cannot go ahead and do the experimentation work in certain instances, because you do not know whether you are going to be harassed with a multitude of nuisance suits. I have in my files a letter from a woman in West Virginia who knows precisely that certain seedings caused her to have a flood that swept away her hen house.

Now, I do not propose to see to it that the Departments of the Interior or Commerce have to protect themselves steadily against people who believe that that flood was caused by seeding in a remote part of the country. It could be. But, if they believe it to be, why not let them sue the Government rather than sue a contractor who happens to be doing it at the request of the Government in precisely the kinds and quantities that the Government has asked him to do it? What is wrong with that?

Mr. EARDLEY. I understand, but the trouble is that if they are allowed to sue the Government, there is not any way of telling how many thousands of suits may be filed every time somebody in some area starts to try to make rain.

Senator ANDERSON. Where will they file those suits?

Mr. EARDLEY. Well, right now, the negligence tort claims are filed in the district courts.

Senator ANDERSON. They would require negligence?

Mr. EARDLEY. At the present time.

Senator ANDERSON. A showing of negligence?

Mr. EARDLEY. A showing of negligence.

Senator ANDERSON. Would this woman who had the chicken coop in West Virginia have trouble in showing negligence when she does not know where the seeding took place?

Mr. EARDLEY. I am afraid that anybody suing anybody under the present state of the art would have trouble showing negligence.

Senator ANDERSON. I am not only afraid of it, but I am sure of it.

Mr. EARDLEY. I do not know enough about it, but it would be extremely difficult. That would not eliminate the possibility of the Government being flooded with litigation.

Senator ANDERSON. No. When they set off the atomic bombs in Las Vegas, Nev., or wherever they were set off a few days ago, there were people who filed a whole set of claims against their insurance companies. They could have filed them against the Government perhaps and they would have gotten about as much from the Government as they are going to get from the insurance companies, which is zero.

Mr. EARDLEY. You commented, yourself, a minute ago that sometimes these things are settled because it is cheaper to settle them than it is to contest the score.

Senator ANDERSON. I happen to be president of an insurance company and I have settled many claims on a nuisance basis—no question about that—but I am talking about liability now, legal liability of it. Did you hear the discussion of the hurricane a few days ago?

Mr. EARDLEY. Yes, I did. That was the first day of the hearings. I attended that day.

Senator ANDERSON. Now, that hurricane had left the Florida coast and started out to sea in the direction of Bermuda. It was seeded when it was out at sea. Because of some circumstance which no one understands, it immediately bent back and started up against the Georgia coast. If that had wiped out great sections of the Georgia coast, do you think people would have had quite a bit of legal activity against the party that did the seeding?

Mr. EARDLEY. It might very well be.

Senator ANDERSON. We have no way of knowing whether that seeding bent it back, or whether the hurricane just turned and came back.

Mr. EARDLEY. That is the problem.

Senator ANDERSON. Now, we are trying to get it to the point where the Government can contract with private agencies to do seeding work for them. We were to have testimony this afternoon by Dr. Krick, who has a large organization covering a good deal of the western part of the country.

Suppose that the Government, in addition to the work that Dr. Krick is already doing, wanted Dr. Krick's organization to seed the extreme western coast of the country and make the test in Oregon referred to, and it did minimize the rainfall. Perhaps I should not say it that way. But, at the same time, simultaneously following the seeding, the rainfall was diminished on the west coast of Oregon and fell very heavily over the eastern section of the State, would you feel it proper that Dr. Krick's organization should be sued?

Mr. EARDLEY. Well, no. He would be an agent of the Government.

Senator ANDERSON. And that is all this is intended to do; is it not?

Mr. EARDLEY. Which bill are you talking about, Senator?

Senator ANDERSON. I was talking about S. 222, but even take S. 5. Does not S. 5, section 5, page 5, do about the same thing?

Mr. EARDLEY. Yes, sir. I do not believe there is actually any legislation necessary to accomplish that.

Senator ANDERSON. You do not?

Mr. EARDLEY. No, sir. We had a comparable situation in which the Ross Construction Co. was sued because of some river work, and the court said, "No, the Ross Construction Co. is acting for the

Government. It is not liable unless the Government is liable, and the Government has sovereign immunity and therefore the Ross Construction Co., an agent, does not have any liability."

Senator ANDERSON. But if we can show you that the General Electric Co. retired from certain fields of activity because counsel advised them not to continue, would that make any difference?

Mr. EARDLEY. Of course, they could be sued; you cannot stop suits.

Senator ANDERSON. That is right.

Mr. EARDLEY. And it might be so burdensome that they would decide to stop activities.

Senator ANDERSON. That is exactly what is happening.

Mr. EARDLEY. Even though they had no liability and would be absolved in the end, but it still would be extremely expensive to General Electric.

Senator ANDERSON. Precisely, and that is exactly what happened; and it is that condition which this legislation attempts to cure.

Mr. EARDLEY. I noticed that in S. 222, section 2—with that we have no quarrel whatsoever. Of course, we feel that contractors should not be expected to bear the expense which would result from activities carried on on behalf of the Government.

Senator CASE. Mr. Chairman, reference to the Legislative Reorganization Act, which embraces the Federal Tort Claims Act, brings to my mind a suggestion I would like to discuss, if I may.

The language in the Federal Torts Claims Act, which relates both to the settlement of claims under $1,000 by the Federal agencies and to the claims which may be filed, limits the settlement of those claims to damage or loss of property on account of personal injury or death caused by the negligence or wrongful act or omission of any employee of the Government while acting within the scope of his office or employment; but, in addition to that, there is section 421, which provides that "the provisions of this title shall not apply to," and then lists a series of claims which the Federal Tort Claims Act may not apply to.

For example, they may not apply to any claim arising out of the combatant activities of the military or naval forces or the Coast Guard during time of war, or any claim for damages caused by fiscal operations of the Treasury, or by the regulation of the monetary system.

Mr. EARDLEY. There are a number of them.

Senator CASE. Or any claims arising from the activities of the Tennessee Valley Authority.

Might it not be desirable to consider adding another sentence in the bill of exceptions to provide that the Federal Tort Claims Act should not apply to any claim arising out of—and then describe whatever activities might arise out of any act which might pass?

Mr. EARDLEY. I think that is a splendid suggestion, a very, very good suggestion. That is the provision where you find discretionary acts are excluded also. That would certainly be satisfactory to the Department.

Senator ANDERSON. Thank you very much.

Dr. Sherwood, I understand you may have to get away early. We will be glad to have you come forward at this time, if you will.

Dr. Sherwood, will you identify yourself?

STATEMENT OF THOMAS K. SHERWOOD, DEAN OF ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

Mr. SHERWOOD. I am dean of engineering at the Massachusetts Institute of Technology. Mr. Chairman, my comments pertain solely to methods of producing fresh water from salt water which are known or established processes, and I have nothing here really that pertains to all of the miscellaneous inventions that have cropped up from time to time and which have not been followed through with development work. So, I cannot pretend to be an expert on the various suggestions, of which there are many and which are illustrated by the one referred to this morning of the Swedish gentleman.

This is a brief statement. Shall I read it, Senator?

Senator ANDERSON. Surely.

Mr. SHERWOOD. The two principal methods of obtaining potable water from sea water involve (1) the removal of the dissolved salts by chemical methods and (2) the evaporation and recovery of pure condensate.

1. Chemical methods: Salt removal from water is possible by the use of ion exchange resins and by the addition of various chemicals. Such methods were developed during World War II by the OSRD and by other agencies. I was connected with the OSRD and was partly responsible for portions of the work done, which led to successful methods applicable on a very small scale, as for emergency use on life rafts. The chemical methods never competed with evaporation processes for shipboard use. The implication there is that the chemical methods are not useful on large-scale economic processes for cheap water. I do not believe that chemical methods need be considered seriously for large installations, as for town water supplies.

2. Evaporation: Evaporation may be effected by (*a*) solar radiation, (*b*) multiple-effect evaporation, (*c*) vapor-compression distillation, or (*d*) a combination of (*b*) and (*c*). Solar-radiation systems use energy from the sun and little power; multiple-effect evaporation requires fuel but little power; vapor-compression distillation requires power with little or no fuel.

In order to visualize a comparison of these methods, it is convenient to compare cost figures for installations designed to produce 2,000,000 gallons of fresh water per day. This is sufficient for a town of some 20,000 people in the East, although Californians use more per capita.

2 (*a*) Solar radiation: Solar stills will produce roughly 1 pound of distilled water per day for each square foot of exposed area on clear days in latitude 40. This means that the solar collectors for the town of 20,000 people would occupy an area of 0.58 square miles. The weather is sometimes cloudy, even in California, so that at least 1 square mile of glass-plate collectors would be needed. The installed cost of the glass and pan collectors would be nearly $1 per square foot, or a total of about $25,000,000. Allowing total fixed charges of 15 percent per year, the water collected would cost from $5 to $10 per 1,000 gallons. I pay 25 cents for 1,000 gallons for delivered town water in Massachusetts.

2 (*b*) Multiple-effect evaporation: This method requires process equipment used in large-scale chemical-plant operations for more than

50 years. There is nothing experimental about it, and an installation for town water could be expected to perform within a few percent of specifications. Assuming low-pressure steam at $0.60 per 1,000 pounds and cooling sea water at $0.10 per 1,000 gallons, the steam and water costs alone would amount to $3.11 per 1,000 gallons, so that the total, including fixed charges and power, would be in the vicinity of $3.80 per 1,000 gallons. The first cost of the installation for 20,000 people would be of the order of $2,200,000 for the evaporators and $2,000,000 for the steam plant.

2 (c) Vapor-compression distillation: This process is not as widely used in industry as multiple-effect evaporation, but is an old technique, and its operation can be predicted with assurance. Equipment employing this process was developed during the last war for use in submarines and arid combat regions. It is reported that the total number of stills manufactured for military purposes had a combined capacity corresponding to the fresh-water needs of more than 1,000,000 men; not at the rate of California consumption, however. They were built in relatively small sizes, however, and large plants for town water would introduce new but not highly difficult engineering problems.

On the basis of the wartime experience with these medium-sized vapor-compression stills, it is estimated that our town of 20,000 people would need 17 large stills, involving a first cost of about $6,000,000, including housing and auxiliaries. Power at $0.01 per kilowatt-hour would be $0.70 per 1,000 gallons, and fixed charges at 15 percent per year would be $1.25, so that the total costs would be of the order of $2.05 per 1,000 gallons. This process offers lower operating and total costs than multiple-effect evaporation, but the plant cost is higher.

I might interject there: I noticed this morning that you have a statement from the Cleaver-Brooks Co. I believe they manufacture this kind of equipment. The equipment was developed in the first instance by Arthur D. Little Co., of Cambridge, Mass., and built during the war for submarines and other military purposes by the E. D. Badger & Sons Co.

Senator ANDERSON. If this Swedish scientist has something to develop that for 2 cents per ton instead of $2, it is worth looking at; is it not?

Mr. SHERWOOD. This is perhaps the point of my story.

(2) Combination plant: A steam power plant may be designed to produce both power and process steam. The power can be used to operate vapor-compression stills and the steam to operate multiple-effect evaporators. The power plant would cost about $254 per kilowatt, and deliver 11 pounds steam per kilowatt-hour. Some 81 percent of the product would come from the vapor-compression stills; the remainder from multiple-effect evaporators.

The entire plant for a town of 20,000 would cost in the neighborhood of $5,700,000. Fixed charges at 15 percent per year would be $1.18 per 1,000 gallons, and fuel and operating costs would be about $0.45 per 1,000 gallons, for a total of perhaps $1.63 per 1,000 gallons.

This would appear to be the most economical of the several possibilities discussed.

A thousand gallons would be about 4 tons.

The following table summarizes the approximate costs of making potable water by these methods:

Dollar cost per 1,000 gallons:
Solar distillation, $5 to $10
Multiple-effect evaporation, $3.80
Vapor-compression distillation, $2.05
Combination plant, $1.63

Typical domestic water, delivered, $0.25—although I must say that cost is highly variable and river water is down to around 4 to 6 cents.

Dollar cost, per year, per person:
Solar distillation, $180 to $360
Multiple-effect evaporation, $137
Vapor-compression distillation, $74

Combination plant, $59—which, of course, one might compare with his fuel bill in New England, which is of that order and magnitude, and it might be said then that if someone in California who did not need fuel had to pay this amount for water he would be in the same boat as the New Englander who had to pay this amount for fuel and very little for water.

Typical domestic water, delivered, $9: These costs may be compared with river-water costs in the vicinity of 4 to 6 cents per 1,000 gallons delivered to towns, and city water charges of $0.20 to $0.30 per 1,000 gallons delivered to homes in many localities.

It should be emphasized that the cost estimates given are approximate, and will vary with location. Reliable cost estimates for a particular plant proposal can be obtained by carrying out careful and complete plant-design studies. Experimental studies are not required.

Conclusion: The expenditure of Federal funds for a plant to demonstrate the production of fresh water from sea water as contemplated by the bill S. 5 is not justified. Such a plant should be built only if there is a clear need for water at $1.60 or more per 1,000 gallons, in which case private capital would be attracted for the venture.

Senator ANDERSON. I talked briefly with Dr. Vannevar Bush about this, and he said when he got into figures that they were just so high that he dropped the subject and said we would only be wasting time on that. I conclude that that is the burden of your testimony.

Mr. SHERWOOD. That is the burden, although it is interesting that these figures presumably would be added to normal water costs, because normal water costs are primary distribution, and, for a town, would continue; that these costs are within threefold or fourfold of what some people pay for town water now in California. It is not economical but it is within gunshot.

Senator ANDERSON. But if there should be a process developed that, as this item this morning indicated, could produce for 8 cents a thousand gallons——

Mr. SHERWOOD. That would be very wonderful. There is a point to watch out for here, however. I was negligent in omitting the figure which can be readily calculated, which is the absolute minimum power cost of power requirement for the separation of water from sea water. This figure is a purely theoretical number below which you cannot go by well-established scientific laws, and I would suggest that, if anyone were looking seriously at a proposal such as the one referred to, it would be wise to compare the suggested figure with this theoretical minimum, because, if it is lower, then I would be quite positive that the man was wrong.

Senator LEHMAN. May I ask you: Are the figures you have given, both with regard to capital investment and operating charges, fully established?

Mr. SHERWOOD. I will tell you briefly the basis of those figures for plant costs, for power-plant costs, for turbine installations, for the multiple-effect evaporator, and for the solar energy. Partly, with my own experience, I have designed plants similar in nature to this, but for current costs I turned to a number of colleagues, one the chief designer of a large company which manufactures and installs a great many multiple-effect evaporator systems. For the solar-energy figures, I turned to my colleague Professor Hottel, who is, I would think the top man in the country on applications of solar energy. For the power-plant figures, I turned to the head of a large consulting-engineer firm who happens to have just finished the design and figuring on a power plant of this type, and to other people to whom I had access for similar figures.

The figure on the cost of the vapor-compression distillers was obtained from Arthur D. Little Co. which does not manufacture them but has had long experience with them.

Senator LEHMAN. Eliminating any Federal participation, supposing a city, a municipality of 20,000 people, felt the need of installing a plant of this sort, would they, in your opinion, be safe in going ahead with it, depending on the cost you have given or that others may have given?

Mr. SHERWOOD. One of the points that I intended to make here was that these processes do not need experiment. The town of 20,000 who wanted one could obtain engineering-design figures from the better engineering concerns which they could trust within a few per centum.

Senator LEHMAN. Thank you.

Senator CORDON. You mentioned, Doctor, something a moment ago about a figure, scientifically established, as to the very floor for costs of getting potable water from sea water. Can you give us the figure?

Mr. SHERWOOD. I cannot. I am sorry about that. I just thought that it would be useful this morning, and I omitted it. It is easy to provide.

Senator CORDON. Would you provide it for the committee?

Mr. SHERWOOD. It is simply the figure on what the second law of thermodynamics tells us about the minimum work required to separate two things. This figure appears in many textbooks. If we had a library handy, I could almost pull it out, but it is a figure which is as solid as the idea that heat will not flow from a cold object to a hot object. It is that kind of basis, and it is, in effect, a related concept. That figure would be the guide as to who is surely wrong.

Senator ANDERSON. Would that figure be above 8 cents per 1,000 gallons?

Mr. SHERWOOD. I am sorry; I cannot tell you. It would be in terms of kilowatt-hours per pound of sea water. It would not be in terms of dollars. The second law does not know about dollars.

Senator ANDERSON. It could be reduced to that?

Mr. SHERWOOD. It could be, if you assumed a power cost; yes.

Senator ANDERSON. You mean it would be operating in a wholly different area?

Mr. SHERWOOD. The standard error in most of these proposals is that they leave out costs. For example, I saw one process described very briefly which was said to produce water from sea water for 90 cents per thousand gallons, but it was perfectly easy in this case, easy to see, that the man was figuring only power, not fixed charges, not fuel, nothing else; no installation costs, no building, and he was figuring power at a half a cent a kilowatt-hour.

In other words, on my basis that would be $1.80 for the power alone, and that is quite a common thing in these estimates of cost.

Senator CASE. You have used 1 cent per kilowatt-hour throughout?

Mr. SHERWOOD. I have used 1 cent where I used electric power. Now, the multiple-effect evaporator system uses very little power. In the combination plant I did not use a power figure. I used the cost of the whole plant, and the fixed charges on it and the actual fuel costs.

Senator CORDON. I wish you would furnish us with that figure.

Mr. SHERWOOD. I will do that, Senator.

(The information requested is as follows:)

WATER FROM SEA WATER

(By Thomas K. Sherwood, dean of engineering, Massachusetts Institute of Technology)

Basic scientific principles provide a method of calculating the irreducible minimum power requirement for separating pure water from normal sea water. The figure is 2.8 kilowatt-hour per 1,000 gallons fresh water. This figure cannot be improved upon by any conceivable process, including those yet to be invented. The calculation is based on the same basic natural law which tells us that heat will not spontaneously pass from a cold object to a hot object, i. e., the so-called second law of thermodynamics. Inventors' claims involving power requirements less than this minimum are bound to be false.

Claims of low-cost operations often omit fixed charges, labor, or other costs. The figures which I gave earlier showed that even if power were free, water obtained by the relatively economical vapor-compression distillation process would cost $1.25 per 1,000 gallons.

Senator ANDERSON. Thank you very much. It is a refreshing thing to have a witness come with as boiled-down statement as you have made and still as accurate as you have made. It is appreciated very much.

Mr. SHERWOOD. Thank you.

Senator ANDERSON. Mr. Gillenwaters, did you want to make a statement in behalf of Dr. Krick this afternoon? We were going to wire Dr. Krick and suggest that he submit a statement, but perhaps you would like to testify this afternoon instead.

Mr. GILLENWATERS. Senator, I am at your pleasure, but I would like to make a statement on behalf of Dr. Krick. We were grounded at St. Louis last night for 6½ hours, and he was called back on an emergency in his family in Denver, a near-fatal accident. We planned that we were going to get the statement into final form this morning. I would be very glad to give you my experience this afternoon, but I think it would be much more informative for your group if Dr. Krick could deliver it personally.

If there would be a limit given when he might appear, in other words, in a matter of 3 or 4 or 5 days, I feel confident that the shock of this family situation will be over, and I think he can attend. I know he is very anxious to be here. It is just one of those things that we could not avoid. I would prefer that he present it.

Senator ANDERSON. We naturally want to accommodate you and want to be very sure that you have the widest opportunity for presentation. I would think perhaps if we could continue this until Thursday or Friday—why do we not leave it that you will notify us later?

Mr. GILLENWATERS. Probably, Senator, next week would fit in better. We are just in the course of moving our old headquarters. It is up to you.

Senator ANDERSON. Mr. Davies.

STATEMENT OF HOWARD DAVIES, INDUSTRIAL PROCESSES CO., INC., PHILADELPHIA, PA.; ACCOMPANIED BY ELMER S. DAVIES, INDUSTRIAL PROCESSES CO., INC.

Mr. ELMER DAVIES. This is my brother, Howard Davies. He will read the statement, Senator.

Mr. HOWARD DAVIES. My name is Howard Davies. I am president of Industrial Processes Co., which company is engaged in the development of certain inventions relating to evaporation and heat-treatment of fluids such as sea water, industrial and chemical fluid wastes, fluid foods such as milk, tomato juice, et cetera, in such a manner as to prevent the deposit of solids upon the heating surfaces. Pilot plants were built, in my place of business in Philadelphia, Pa., and numerous performances of these plants have amply demonstrated the practical application and utility of the basic claims embodied in our inventions.

An article appearing in Collier's, December 5, 1949, issue, entitled "Get Off of Route 25" poses the challenge to American inventors by its author, Mr. Charles F. Kettering, of General Motors Corp., to design apparatus and develop methods of extraction of both potable water and the many desirable elements contained in the inexhaustible sea. Over untold centuries, the sea has accumulated from the land areas by drainage countless tons of essential elements. The rate of industrial expansion is now exceeding available and potential supplies of many such elements that civilization must have in order to maintain its present pace of growth. In Mr. Kettering's opinion, human problems exist only to be solved. If there were no problems, there would be no solutions.

The ever-present problem of diminished water supply and falling water tables demands immediate attention by the authorities responsible for the common welfare. Since the problem is national in scope, the solution must be effected by the combined resources of both private industry and Government. All phases of the subject must be coordinated, and all assistance must be rendered by all groups in each locality, in order to genuinely improve the water situation for the entire Nation. Since this committee is interested in potentialities that may be derived from sea water, we submit the following data in the hope that some measure of assistance may be rendered on the subject.

As you may know, the evaporation of liquids containing solid matter involves the problem of preventing fouling of the heating surfaces, which fouling requires frequent shut-downs for removal of the solids deposited on the heating surfaces during the application of heat. Extensive experience and research in processing milk prod-

ucts—that is by my brother—culminated in the inventions mentioned above, and, in our opinion, together with the opinions expressed by recognized engineers, offers a practical solution to this problem of preventing the coating or fouling of the heating surfaces of evaporators. A coating of one one-hundredth of an inch of sea-water solids on the evaporator surfaces, which coating forms within approximately 3 hours after the evaporator is started, reduces the heat exchange efficiency of the evaporator 40 percent. The Campbell Soup Co. sterilized tomato juice by running it through heat exchanges. They can run 1 hour and have to shut down to clean the tubes. Our process provides direct heat transfer without any loss of heat-exchange efficiency, and requires no shut-downs for removal of accumulated solids from the heating surfaces of the evaporator.

Another feature which should be of genuine interest for the defense effort is that the apparatus operates at relatively low pressure, and, hence, the surfaces over which the treated fluids flow may be constructed of ceramics which may be acid-, alkali-, and salt-resistant. The construction of the entire unit is reduced to the realm of low-cost readily available and nondefense material. The amount of metal required for structural support may be of the lower grade since the entire unit is operated at low pressures, not to exceed 25 pounds. The combustion chamber will require some priority metals.

The cost factor naturally enters into any processing problem. To confine the problem to recovery of potable water from sea water would render it economically impractical.

We use no tubes. We run our evaporation with a low pressure. That is, the surfaces over which it may run are constructed of ceramics or concrete, which may be acid or alkali. In other words, this is in effect nothing more than a single-effect evaporator with the efficiency of that evaporator. However, if the heat-treatment and evaporation of sea water produces many end products, the problem then has a solution.

Steam production direct from sea water is one of the phases of our inventions. As you know, boiler feed water must be free of solids, or treated, for either steam or hot-water use. Conventional boilers cannot use sea water because of the fouling and corrosive effects that would occur. In areas where fresh water is either scarce or unavailable such as exists in arid coastal areas, our inventions would permit the direct use of sea water, or saline waters from wells for steam production, together with condensing the exhaust steam for potable water supplies for human and animal use in the locality. The steam generators could be constructed for the desired pressures and temperatures if power-driven units were to be operated. The cost of power may be charged at average rates and deducted from the total cost of the unit operation, which would represent the cost of potable water. If we go deeper into this type of set-up we will enter the field of chemical extraction involved in the treatment of the concentrated brine or sea water, an end product of the steam-power-production angle.

We have on file in connection with this invention a tentative design whereby we use this evaporator at high pressure to generate steam to run turbines and use the exhaust from the turbines to be condensed for potable water. The average turbine will use about 1 gallon of water per kilowatt produced, so that if we had a plant developing, say,

10,000 kilowatts you ought to get approximately 10,000 gallons of water per hour or about 240,000 gallons per day.

The cost of the water then would be the difference between the efficiency of the standard boiler as used today and the efficiency of this unit. We tested a small unit which we have up there, and working at 60 pounds pressure and 800° temperature we achieved efficiency of the boiler at about 80 percent, which is comparable to pretty good steam plants today.

Extraction of chemical elements of sea water is economically feasible if the water content has been reduced to the point of crystallization and that requires removal of most of the water, either by natural air drying, or by mechanical means. Our invention permits a high degree of concentration, in addition to recovering vapors by fractional distillation at desired heats. The degree of solubility of each element present in sea water at various temperatures offers the means of separation of each element. For instance, common salt, or sodium chloride, will gravitate to the bottom of air-drying pans when the density of the salt solution has reached a certain point. A higher degree of density or concentration of the salt solution will precipitate another form of crystal, such as calcium or potassium hydroxide, as in the case of chemical extraction of chemicals in the Dead Sea in Israel. The sea contains an average of solids of 3.5 percent. There are four major products in sea water that lend themselves to recovery at low cost: Magnesium, chlorine, sodium, and sulfur. There are many others that may be extracted.

It appears that the most practical solution to the problem of extracting desired salts from sea water involves the construction of a series of evaporating units, each unit to operate at a temperature that will precipitate a certain salt, the effluent from the first unit to pass from the depositing tanks to a second evaporating unit where the temperature and concentration of the solution will be attained to precipitate another salt, the effluent from this second unit to pass into a third evaporating unit to remove another salt at the temperature and concentration required for such action, et cetera. A chemist can readily determine the temperatures and solubility of each salt that is to be removed so that a continuous, uninterrupted operation may be established, and, in each unit, the extraction of potable water continues. The solid salts thus recovered can then be treated with reagents for further extraction, and/or refinement.

We are not chemists, so those are things that are probably just a little bit beyond us.

We offer another suggestion that may be of interest to this committee. The billions of gallons of water that are daily dumped into our streams in the form of industrial and chemical wastes offers an unusual opportunity to assist in converting our water resources. The current difficulty is one of recovery of both water and solid content of such wastes by conventional methods which are too costly. As in the case of sea water, the problem is to provide an evaporating process that will not foul the heating surfaces. In our opinion, and in the opinion expressed by recognized chemical engineers, our inventions offer the most promising solution yet advanced, since sludge content of such wastes may be concentrated to a degree of salvage value which may defray the cost of evaporation in a manner that would justify the investment for evaporating units. Four hundred million dollars are

spent annually for stream pollution correction and $8 billion are required over a 10-year period to meet the demand for maintaining the health standards of our communities. It appears to us that purification of, and the recovery of values from industrial waste waters will materially help improve the water supply situation while simultaneously solving the stream pollution problem.

Since the experimental units were completed as late as May 1950 we are not in a position to submit actual costs with respect to the various phases to which our inventions may apply. We do have numerous records relating to the production of steam at various pressures and temperatures derived from both fresh and sea water per pound of fuel used. Our objective was to demonstrate the practical application of our basic claims embodied in the inventions. This has been done and the facts are now matters of record. Of course, this is a small unit.

I might go on and add from something else: Realizing that our system of evaporation in its present state has about the same efficiency as a conventional single-effect evaporator, it has been our aim to devise some means of increasing its efficiency. Just this past week I submitted to Dr. Agnew, of the Franklin Institute of this city, some plans and figures on a system of evaporation, somewhat different from our superheated steam system, but which would use the steam produced in this system for its source of energy. Dr. Agnew said, after studying our plans, that he could not see any reason why it would not work, and that it looked practical as far as he could see. This system, if it proves to be what we have figured, would have probably better efficiency than vapor compression systems, without the use of any mechanical compression. It has the added advantage that any existing evaporating plant, single- or multiple-effect, could readily be converted to a more efficient system. We have started to construct a small model, and will know within a week or so whether it will confirm our theory.

Dr. Agnew also stated that he had talked to the board of governors briefly about the plans which I submitted to them, and while on such short notice they were not willing to commit themselves to the extent that they would make a statement saying that the apparatus would work, they did consider it of sufficient merit that they would be very much interested in its development. And, as the Franklin Institute is known to be one of the foremost scientific organizations in the United States, and the world, to us this was most encouraging.

Summarizing, we submit the following for your consideration:

(1) A new, novel and practical approach to evaporating sea water is embodied in our inventions and offers a solution to the age-long problem of devising a method and apparatus that would provide a continuous, uninterrupted evaporating process of fluids containing substances that foul the heating surfaces.

(2) The cost of potable water recovery from sea water can be defrayed if the end products, such as sea water salt compounds, are included in the evaporating process. Our invention makes this possible, in our opinion.

(3) Our invention offers a solution to the problem of stream pollution, by recovering potable water, and waste solids for reuse and/or salvage end products, in addition to removing health hazards from the streams.

We appreciate the opportunity of appearing before this committee and trust that what we have to offer may be of material assistance to the objective indicated in Senate bill No. 5, introduced by Senator O'Mahoney.

We did not deem it advisable to submit technical data relating to our invention to the committee, but suggest that if interested in what we have to offer, we will demonstrate the performance of the units to any group you may designate.

The various features involved in the methods and apparatus which have been perfected by myself and my brother, Mr. Elmer S. Davies of Washington, D. C., are all matters of record in the office of our patent attorneys, Messrs. Smith, Michael, and Gardiner, Woodward Building, Washington 5, D. C. Pilot plants effectively demonstrating the operativeness, utility, and efficiency of the methods and apparatus, have been constructed and successfully operated in Philadelphia, Pa., and have been the subject of frequent demonstrations before qualified engineers, Government officials, and others directly interested in evaporation, power development, and related operation. These demonstrations have proved beyond doubt the effectiveness of our methods and apparatus for satisfactorily performing their intended purposes.

Senator ANDERSON. Thank you, Mr. Davies. We appreciate your coming down here.

Mr. Hosler, I understand that you might like to go on this afternoon, but we are going to try to get through here. Because of the absence of Dr. Krick we may be able to finish up most of what we have to do this morning, so I think you had better go ahead. Would you give your name for the record, please?

STATEMENT OF HANS H. NEUBERGER, PROFESSOR OF METEOROLOGY AND CHIEF OF DIVISION OF METEOROLOGY, PENNSYLVANIA STATE COLLEGE, STATE COLLEGE, PA., ACCOMPANIED BY CHARLES L. HOSLER, STAFF MEMBER, PENNSYLVANIA STATE COLLEGE

Mr. NEUBERGER. I am Hans Neuberger, professor of meteorology and chief of the division of meteorology at the Pennsylvania State College. I am accompanied by Mr. Charles Hosler, who is a staff member of the same division. We appear before this committee as individuals. The views we express here are our own and not necessarily those of the Pennsylvania State College.

My own interest and active work in the field of atmospheric conditions go back 21 years, when I was a pupil of the late Prof. Albert Wigand at the University of Hamburg. I was introduced into this branch of meteorology by Wigand's scientific attempts at cloud modification, which roughly coincided with those of Veraart in Holland who, as early as 1930, seeded clouds with dry ice and other substances, a method recently revived by other scientists.

At the Penn State Meteorological Laboratory, we have been conducting a research program in various phases of the basic problems of atmospheric condensation for the past several years.

We believe that this committee may be interested in some of the results of our work, because these results appear amenable only to an

interpretation that is at some variance with that proposed by other investigators. For example, a laboratory study of the effects of certain chemicals, such as silver iodide, on the coalescability of cloud droplets at temperatures above the freezing point has shown that the role of such chemicals in atmospheric condensation is not necessarily one of "sublimation" nuclei.

Other results of our work, on which Mr. Hosler will report, are likewise different from those obtained by some other researchers. In general, our results, aside from their implications with respect to scientific concepts, appear to demonstrate the need for further extensive and coordinated research efforts, particularly in the fundamental facets of the problem, before it can be established with any degree of confidence what it is that may need legislative controls.

With the permission of this committee, I would suggest that perhaps questions you may have would be postponed until Mr. Hosler has had a chance to present his views, because some of the answers may be contained in his remarks.

Senator ANDERSON. Very well; go ahead, Mr. Hosler.

Mr. HOSLER. I have a prepared statement here, a written statement, but I do not intend to read it as such. I would like to submit it, however, and cover the main points of that statement as I go along.

Senator ANDERSON. Very well.

Senator CORDON. I suggest, Mr. Chairman, that the complete written statement appear in the record.

Senator ANDERSON. Without objection, the complete statement will appear in the record.

(The prepared statement submitted by Mr. Hosler is as follows:)

STATEMENT OF C. L. HOSLER, DIVISION OF METEOROLOGY, PENNSYLVANIA STATE COLLEGE

A number of recent experiments both with natural and artificial clouds have demonstrated that clouds consisting of supercooled water droplets can be modified to the extent of causing them to be transformed to ice crystal clouds or to evaporate. The question as to why these supercooled clouds exist, and why the introduction of certain substances into these clouds will result in crystallization or evaporation has by no means been completely answered.

One explanation which has been offered for the artificial crystallization of supercooled clouds, is based upon the presence of what have been termed "sublimation" nuclei. Certain chemicals which are particularly active in crystallizing supercooled clouds have been assumed to be active because of their crystal structure being similar to that of ice; hence, the idea arose that such chemicals serve as sublimation nuclei.

Many aspects of the experiments, that have thus far been conducted, suggest that the observed results of "seeding" are not necessarily explained in this way. Silver iodide smokes produced by extreme heat and rapid cooling, in all probability do not consist of hexagonal crystals. In fact, experiments by Tamman show that these smokes are composed of glassy particles which are not crystalline. Laboratory experiments have demonstrated that materials can be used to "seed" clouds, that are neither hexagonal nor crystalline. For example: Thallium iodide, elemental iodine, elemental lead, and the gas ozone will all lead to the crystallization of a supercooled cloud at temperatures far above the spontaneous freezing point of the cloud droplets.

Experiments, which have been repeated several times in the last 100 years, have indisputedly shown that the temperature, at which small water droplets spontaneously freeze, becomes lower as the diameter of the drops is decreased. This lowering of the spontaneous freezing point of water drops by decreasing the drop size is a basic phenomenon which must be explained if we are to understand the formation of ice in clouds. It is obviously not a case of certain nuceli being absent to a greater degree as the drops become smaller. The reason for this phenomenon must lie in some change of the internal structure of the drops them-

selves. This structure is a function of size, and the change in structure in some way deters crystallization.

An explanation as to how the structure of water plays such a role has been offered by W. A. Weyl. The explanation is based upon the concept that a surface consists primarily of the most polarizable ions, because polarizability permits an adjustment of the force field of surface ions and consequently a lowering of the surface-free energy of the system. Polarizability is a property which can be measured by the molar refraction of a molecule or ion. Among the oxides, H_2O represents an extreme case because the hydrogen ion has no electrons and hence zero polarizability, so that the surface of water contains oxygen ions only. The net result is the formation of an electric double layer on an electrically neutral particle, such that negatively charged oxygen ions are on the outside with positively charged ions slightly recessed.

Since the atomic arrangement of the surface differs from that in the interior, some finite distance will be required for the transition from the surface to the bulk structure. Decreasing temperature increases the thickness of the transition layer which is required to keep the energy of the system at a minimum. Ice, because of its greater rigidity in its structure requirements, requires a thicker transition layer than liquid water. For this reason, a given small amount of water at a temperature below the freezing point may be stable as a liquid drop, but not as an ice crystal. Freezing of such supercooled drops can occur if the temperature is lowered or if the droplet size is increased to the point where there is "room" for the necessary transition layer at that temperature. Solid CO_2 being at an extremely low temperature will cause crystallization of the drops by cooling alone. Likewise, the introduction of highly polarizable ions into the surface of supercooled water drops, will lower the surface-free energy and weaken the electric double layer to such an extent that the spontaneous freezing point will be raised. In general, if the surface energy is lowered, a lesser zone of transition is necessary to keep this energy at a minimum and thus the supercooled drops can freeze. Lead, thallium iodide, and silver iodide all present the necessary polarizable ions to the droplet surface and this induces crystallization.

The surface structure of water also explains some other peculiarities of water, for instance, the sticking together of ice crystals to form snow-flakes which consist of a large number of individual crystals. Snow will pile up on surfaces such as tree branches in a manner unlike any other crystalline material because of this stickiness. According to the above theory, any ice surface above a certain temperature, will be covered by a thin film of water of a distorted structure. This water must persist on an ice surface; but when two such surfaces come in contact with each other, there is no necessity for the existence of a water film and it freezes. The slipperiness of ice is also caused by this layer of water which must persist between ice and any other substance, such as the steel of ice skates, sled runners, etc.

Experiments are by no means complete, which would establish beyond doubt, what the exact explanation is for the supercooling and crystallization of water. However, preliminary experiments indicate that this concept deserves further vigorous investigation.

There is little doubt that an understanding of the mechanism involved in precipitation is partially dependent upon a correct interpretation of these phenomena. It must be emphasized, however, that to state, at this time that we know how to make rain or how rain forms naturally is entirely premature. The coexistence of ice and water in a cloud is merely one of the possible causes of precipitation. It has by no means been established that this is the only mechanism responsible for precipitation. Even if future research should demonstrate that precipitation forms in this way, it must still be demonstrated that causing ice crystals to form artificially will produce rain where it would not have been produced by natural causes. Without adequate knowledge of the fundamentals of supercooling and crystallization processes, we cannot intelligently interpret the results of "seeding" experiments, and hence we cannot hope to proceed efficiently on the way to prediction or control of natural meteorological events.

Mr. HOSLER. I think there is little doubt and little disagreement among everyone that clouds can be altered by seeding with silver iodide or carbon dioxide or what have you. There is quite a bit of disagreement, as you are well aware by this time, on what can be accomplished by this degree of modification of these supercooled clouds.

I think, to get to the heart of the problem and to really find out what can be accomplished, we must have a basic understanding of the phenomenon of supercooling and exactly how these substances somehow upset the stability of these supercooled clouds. It has been known for a hundred years now that supercooled water droplets will freeze at a temperature depending upon their drop diameter.

It is fairly obvious from experiments that have demonstrated this that it is not a case of the absence or presence of some type of nuclei which changes the spontaneous freezing point of the droplets, but is some property of the droplets themselves, apparently some fundamental change in the surface structure or interior structure of the droplets.

Another way that this can be demonstrated very well is by some experiments which we have performed with materials other than silver iodide, which are not hexagonal nor which are even necessarily crystalline. We have seeded clouds successfully with elemental lead, and as Dr. Schaefer has reported, with elemental iodine. We have seeded clouds with thallium iodide. We have found of the iodides tested any iodide will transform supercooled clouds to ice crystal clouds at temperatures above what has been termed spontaneous freezing point in the vicinity of minus 39°.

Senator ANDERSON. Where are you doing this work?

Mr. HOSLER. At the Pennsylvania State College.

Senator ANDERSON. From planes?

Mr. HOSLER. These are laboratory experiments. We have kept our experiments down to earth.

Senator ANDERSON. I do not think that is the best rule. Is it actually that those things which are done in the laboratory are down to earth and those things done in the skies are not common sense?

Mr. HOSLER. To express personally my feeling, I feel things of such magnitude as this should be proved in the laboratory before the public or anyone else is subjected to the possible results.

Senator ANDERSON. How did you feel about the atomic bomb?

Mr. HOSLER. I am not here to discuss the atomic bomb.

Senator ANDERSON. I am just asking that.

Mr. HOSLER. My work has been with cloud physics primarily.

Senator ANDERSON. Go ahead.

Mr. HOSLER. We have an explanation. We are not saying it is the explanation; we have an explanation—an explanation upon which we would like to do much more investigation before stating that it is the explanation.

It is based on the surface structure of water rather than on any sublimation nuclei, the existence of which has been doubted by many scientists in the past, not only by myself, on theoretical grounds and on experimental grounds. We feel that the seeding of supercooled clouds results in the freezing of existing droplets.

Now, it may seem irrelevant whether the seeding occurs, whether the glaciation of the cloud occurs for one reason or another, just so it occurs. However, until we know precisely what the reason is for the freezing of those clouds, we cannot evaluate the experiment because we do not know what would have occurred naturally, and there are a great number of natural substances in the atmosphere.

Obviously it rained long before 1920 or 1930 or 1940, for that matter, and there are natural substances in the atmosphere which are capable of seeding the clouds in themselves.

I personally would be in favor of an explanation giving ozone, a gas which is produced by ultraviolet radiation or by potential gradings in clouds, as being a very important element in cloud-seeding processes, natural cloud-seeding processes, and I feel that until we have a thorough understanding of what it is that freezes these droplets and when it is apt to occur, we cannot evaluate experiments in the artificial seeding of clouds.

We cannot determine what would have been the outcome if we had not seeded, and by the same token I think there has been a tendency to accept the fact that the mere creation of ice crystals in a cloud will of itself cause that cloud to precipitate and cause rain to fall from it.

The Bergerson-Findeisen theory which is referred to, which is based upon the creation of a colloidal instability in a cloud by simultaneously having in the cloud ice and water droplets, is but one of the explanations which has been given for the creation of precipitation from clouds.

Quite obviously, as all people know, a great deal of rain falls in the Tropics from clouds which do not even reach the freezing level. Quite obviously ice crystals are playing no part in the formation of this precipitation, and it is not unreasonable then to suspect that other processes may also be important in extratropical rainfall.

Senator LEHMAN. May I ask one question? You say that all your experiments have been in the laboratory. Have you or any other members of your organization had the chance of observing or studying or evaluating the practical work done by Krick and his organization or by the city of New York in the Catskills?

Mr. HOSLER. We have followed those experiments as they have gone along with a great deal of interest, and I wish to express my admiration for all those people who have been engaged in those experiments, for their enthusiasm and for the great stimulus that has been given the field of physical meteorology by bringing this thing to the forefront.

I believe some 20 years ago when Veraart was doing his experiments in Holland and he asked for appropriations to carry on research to determine the feasibility of seeding clouds for artificial precipitation, he was refused the appropriation. I feel that we would probably not be here today if the Dutch Government had given him what he desired and the thing could have been threshed out at that time, legal implications and otherwise.

Senator CORDON. You think, then, that the up-from-earth rather than the down-to-earth experiments that have been made here in the last few years have a very definite value in this picture?

Mr. HOSLER. You mean by that laboratory experiments?

Senator CORDON. I mean the ones that are made up in the clouds by the use of silver iodide shot up to the clouds or dry ice dropped down on the clouds.

Mr. NEUBERGER. I feel that while this type of experiment is definitely of great value, it is somewhat premature. The usual process is to establish a theory and then test the theory by imitating the natural processes and see whether you can make nature follow the trends that you have established theoretically.

Personally, I believe that some of the work is definitely somewhat premature in its aspects.

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Senator CASE. Mr. Chairman, I would like to ask what would be recommended as a procedure by which we could stop the experimentation in the clouds.

Mr. HOSLER. I do not think you can stop the experimentation in the clouds, and I would not propose that. I think there should be outdoor experiments. I do not mean to imply that we should do all of our experiments in the laboratory, but I feel that we should keep a fast pace in the laboratory so that we can more readily evaluate those experiments which are done out of doors.

I am not sorry one bit that experiments have been conducted outdoors. I think it has been a great stimulus, perhaps a necessary stimulus, to laboratory research. However, I feel that we have by no means an explanation.

We do not know why silver iodide will cause a cloud to glaciate nor do we have any reason to believe—we have reason to believe, but we do not have any reason to believe without doubts—that the mere production of ice crystals in clouds will cause precipitation. We do know for certain we can cause dissipation of clouds.

I believe you saw some photographs of that, and that is entirely possible—to evaporate what we call a stable type of cloud where the formative process did not involve a great deal of energy, and it is merely a matter of setting the thing in one direction or the other, but we do not have sufficient information about the production of precipitation by natural means in clouds to evaluate experiments in the artificial production of precipitation.

Senator LEHMAN. Do you feel that the practical work that has been done has either established or confirmed any theoretical principles?

Mr. HOSLER. No; for the simple reason that we do not know that would have occurred naturally.

Senator LEHMAN. Now, one of the witnesses here the other day testified that, with respect to the experiments carried on in the Catskills for the city of New York, the precipitation was, I think, 14 percent greater during the period in which he was operating than the average precipitation over a period of 13 years. Do you think that that has any weight? I know Senator Cordon raised very, very vital questions in connection with that.

Mr. HOSLER. I by no means feel that that is a significant piece of information. I might add, I was reading, prior to coming down here, in a French agricultural bulletin of the early 1900's, that they had a cannon that they fired in the air to prevent hailstorms, but that they had to fire at the precise moment, not too late or not too soon, and they did those experiments from 1901 to 1910, and they had quite a significant statistical result. From 1901 to 1910, they had, in dollars and cents volume, one-fifth the hail damage they had had for the previous 10 years. However, those experiments later proved to be a hoax. I do not mean to imply that the present experiments are meant to be a hoax.

Senator ANDERSON. How do you evaluate these present experiments? You say that you appreciate the value of Dr. Krick's work, for example. He has reported some results in the northeastern corner of Mexico. How do you go about evaluating that?

Mr. HOSLER. I should like to point out that those results that I have evaluated are only those which have been published in the technical bulletins.

Senator ANDERSON. That is the very point. You cannot find out what Dr. Krick is doing. You do not know what he is putting in the atmosphere. You do not know when he is putting in the atmosphere, nor where.

Mr. HOSLER. It is a very important scientific procedure.

Senator ANDERSON. How do you find out what he is doing?

Mr. HOSLER. I have no way of finding that out. I read most of that in the newspapers, Life magazine. I find most of it has been published there.

Senator ANDERSON. None of it has been published there. Do you think that it would be desirable to know what he is putting into the atmosphere?

Mr. HOSLER. Quite desirable.

Senator ANDERSON. That is what we are trying to get at by this legislation. As it is now, any person who can buy a generator—which once cost several thousands, and I understand now is down to $150, $200, at the most $300—can start his own little stream of silver iodide into the air.

Mr. HOSLER. That is correct; which is a very dangerous thing.

Senator ANDERSON. Do you think that is desirable?

Mr. HOSLER. No, I do not feel it is desirable. I acquire severe headaches myself, from inhaling silver iodide, which is a poison.

Senator ANDERSON. So that you know it is not desirable for every person to do that, without some organization having a control of it. There cannot be any control on the experiment unless you know what is going into the atmosphere.

Mr. HOSLER. That is quite essential. That is quite a good point.

Senator ANDERSON. I think it is fine that you have spent the time and work that you have in the laboratory. I hope it continues rapidly. I think it has to be tested very carefully and examined carefully, and somebody has to be not completely sold but willing to try further experiments. At the same time I do think we need to know what is going on around the world and what is being put into the atmosphere at the present time.

Mr. HOSLER. In the testimony this morning there was the question of negligence. The question in my mind is if it is not negligent to try something on the public, so to speak, which has not been proven in the laboratory. The doctors are not permitted to prescribe medicines which have not been previously tested, and I feel that in tampering with the atmosphere, perhaps the same might apply.

Senator LEHMAN. Mr. Hosler, may I ask you this: Assuming that there have been real results in the seeding of clouds with silver iodide, our reports have been that the effect of that may be very widespread. In other words, it might be used in the Catskills and might extend way over into Massachusetts, New England, or down into Pennsylvania, Ohio, and even farther. Have you any thoughts on that?

Mr. HOSLER. My experience in the laboratory—and, I believe, as has been reported in prior testimony—has been that silver iodide, the aging effect, might considerably limit the extent to which it could be active over a long distance from the originating source.

I feel too that, if introduced into clouds where precipitation was occurring, it would rapidly be precipitated out with the cloud elements.

Senator CASE. Mr. Chairman, I recall being in Hawaii during World War II. There was a native Hawaiian who had attended

Harvard, but he had an assignment at that particular time to work with the new troops that were being oriented for service in the Pacific. His particular job was not to teach them what he had learned at Harvard but it was to teach them what he had learned as a native Hawaiian about the use of herbs and plants that might be found growing in the jungle countries where these boys might be separated from their companies or might be taken prisoners. His job was to tell them what plants and what herbs the natives of the jungles had found which could be used for medicine under certain conditions, what could be used for food, what had poisonous effects, and so forth.

I am sure the natives who used those herbs could not be told the scientific reactions when they used some of the plants, but, nevertheless, the people did not cease using them, and I think we are in the position of finding certain of these things work. We may not be able to explain the character of them, but someone is going to go ahead and do these things. The proposal of these bills is to, somehow, bring together this practical knowledge and make it available to the laboratory people to find out why certain things happen, the ways of perhaps improving the techniques.

We are in the position that people we know are actually doing these things.

Mr. HOSLER. I am not opposing any particular bill. I am not opposing or proposing any particular bill. I merely came down here to testify and to demonstrate that there are some differences of opinion as to the explanation of seeding, and, therefore, there might be considerable difference of interpretation of the results of seeding on the basis that there may be natural seeding occurring in the clouds which we do not know about.

Senator CASE. You would actually favor a procedure which would collect this experimental information?

Mr. HOSLER. I certainly would; yes; and I think that the agency to do that would be some professional organization like the Meteorological Society, the American Meteorological Society.

Senator LEHMAN. You say that you do not think the time has come yet where there ought to be any Federal intervention. One of the purposes of these bills, as I understand it, Mr. Chairman, is not only to coordinate the activities but also to control experimentation, through licensing and otherwise. You feel that the situation has become sufficiently serious that the Government should license experimentation and control it to some extent?

Mr. HOSLER. Yes. I feel that there must be some Government supervision and Government aid, but I feel that an organization like the American Meteorological Society should be the clearing house for information. Of necessity, Government aid would be required to get them the information.

Senator ANDERSON. What has the American Meteorological Society done in this field?

Mr. HOSLER. What have they done in this field?

Senator ANDERSON. Yes.

Mr. HOSLER. You mean in the way of research?

Senator ANDERSON. I am just trying to find out why they should do the clearing on it. They have not believed that it was possible. Therefore, they have not seeded anywhere.

Mr. HOSLER. Let us not say they have not believed it is possible. It is true that it seems to be a matter of belief, it seems to be a matter of faith. Seeding is more or less like praying. It seems to be, at this point, a matter of faith.

That is not the type of thing we generally make legislation about, matters of faith; do we? Generally, we make legislation where something exists as a fact, and it has not been established as a fact yet that we can modify weather.

Senator ANDERSON. Is there a story about how they found gunpowder?

Mr. HOSLER. I imagine there is a story, and that has been used for cloud seeding also. Congress appropriated $9,000 for that purpose.

Senator ANDERSON. Did they know what they were doing with gunpowder when they first used it?

Mr. HOSLER. I imagine they used it for fireworks.

Senator ANDERSON. They dusted a little substance down there in a rock and threw it at the enemy.

Mr. HOSLER. I am not admitting that we have demonstrated yet that we can modify the weather. The opinion would seem to be that the clouds were floating around in the sky like so many cows in a pasture waiting to be milked, and we have to go up there and do it. There are a lot of farmers that do not understand how the cows produce milk, but they go out and milk them.

Senator ANDERSON. Do you think they ought not to be milked until they know?

Mr. HOSLER. No; because we know that milk comes out, but we do not know that we can produce precipitation from clouds. That has not been demonstrated and not accepted by most meteorologists.

Senator ANDERSON. Now you had a fellow like Dr. Bush who is not regarded as completely stupid as a scientist, and he believes it can be done, because he sees it happen.

Mr. HOSLER. I saw a man pull a rabbit out of a hat once, and he did it by saying two funny words, and I cannot prove otherwise. Therefore, I think we should have legislation to produce rabbits and send the meat to India.

Mr. NEUBERGER. I believe Mr. Hosler expressed himself a little bit too strongly. I believe the question of whether it has been established or not is probably not so much entering this whole proposition because while in some cases there is such strong evidence, such a great degree of confidence in the experiment, that we cannot ignore it and cannot deny it, there are other instances with probably equal probability and equal frequency where we try to do something about cloud seeding and nothing happens.

As a consequence any legislation involving, say, a regulation of such experiments would have to specify in some measure under what conditions we should attempt or not attempt cloud seeding because of possible damaging or disadvantageous results. However, at this stage of the art we are in no position to precisely outline the limits of such legislation.

As a consequence I believe it may, instead of stimulating and coordinating the research, legislation might actually stymie further research.

Senator CORDON. Let us say, if I may paraphrase the late Mr. Cleveland, that we have here a condition and not a theory. There

are people seeding clouds. They are getting paid for it. Others are seeding clouds because they are interested in a study of the effect, and so forth.

Now that is a condition, that is a fact. They are going ahead and doing it. What should the Government do about it? If we cannot say that they make rain by it, neither can we say that they cannot make rain by it.

We say with reference to it, it may have this result purely local, it may have a result far from local. It may have a result and we do not know what that result may be.

Mr. NEUBERGER. Precisely.

Senator CORDON. Then facing the condition, is it not altogether proper for the Government in its primary authority over interstate commerce, over those matters which are beyond the ability of a single State to control, to step in, even in its ignorance as to what may be the effects of what is being done, and at least set up some organization that can effect some control even though the controls go no further than to require the compilation of data which may be available to you, for example, in the laboratory, to the Weather Bureau, to the various agencies of Government interested in weather, to people throughout the United States who may be curious about the thing, and so on? Is that not the proper step for the Government to take at this time, considering all factors?

Mr. NEUBERGER. I imagine that some sort of legislation that would provide licensing requirements for people actively engaged in projects, if it is for no other reason than for protecting themselves against, say, the toxic effect of the substances used and also for protecting them financially against lawsuits which may not have foundation in fact because it cannot be proven, no matter what court, whether they have or have not made the rain that is claimed to have caused damage, but I believe that it should be a fairly liberal type of legislation that would not retard any progress but would precisely achieve what you have in mind, namely coordination of research and perhaps an overall plan for the design of experiments and not a haphazard shooting off of substances into the atmosphere that may or may not have an effect.

Senator ANDERSON. I think I would agree with that a thousand percent. I think if Dr. Hosler and I sat down to discuss it, we would come out very close together because what he has been saying is exactly the purpose of this legislation, as I see it.

There have been a great many people who have believed, for example, that there is such a thing as the analogy system of weather predicting. They know that storms took place in a certain spot out on the ocean and that months afterward or weeks afterward a certain storm took place in other sections of this country, and by taking charts that have been carefully made up they can come in and say, "We believe there will be a storm in your area as of a certain date," and by analogy it seems to happen again.

No seeding might have entered into it at all. It could easily have been just the natural force of circumstances producing that result.

In the meantime, people are going to pay out hundreds of thousands of dollars for weather services from private groups, and the Government is not going to find out what is going on because they will not know what these people are doing. Any effort to find out what

seeders put into the air results in a statement that that information is not available.

You saw in the New York case, when we had testimony on it, that because of the possible legal implications they were not going to tell exactly what they did, because there have been a whole series of damage suits filed. It would seem to me very desirable that we know exactly what everyone is doing and what he is putting into the air.

Then I think those results ought to be carefully studied by any group of scientists that wishes to, and I think most of all by the American Meteorological Society. I quite agree that that is one group that ought to look at this with tremendous interest and can probably give us the greatest guidance.

For example, when it comes to licensing people to go out and make rain, I think we ought to make sure that the man who is doing it is a meteorologist or has a meteorologist in his organization. If there were some way of requiring membership in some such society as that, I would not be opposed to that.

I think that perhaps the purpose of the bill, at least my purpose in it, is somewhat confused because I am not trying to stop experimentation. I am not trying to prevent a single rancher from having the rain maker that he wants to have, but I think the country is entitled to know what is going on, and I think that it has a right then to study what the seeding pattern has been and submit that pattern to a group of scientists and say, "Do you think, having regard for the fact that 20 pounds of silver iodide was put into the air every week in New Mexico and 11 pounds in Colorado and 42 pounds in Arizona, that this flood in the Ohio was in any way connected?"

Only until we do that I do not think we will know what is going on. That seems to be what I think we should do before we find what has taken place. The amount of silver iodide that we put into the air this year will be a wholly fantastic figure, I think.

Mr. NEUBERGER. Mr. Chairman, if I may make a suggestion, I believe from the standpoint of the efficiency of coordinating efforts, while I certainly would suggest the Meteorological Society should be consulted as to the qualification of men attempting to seed clouds or attempting to make rain, I believe that the United States Weather Bureau should be used, by all means, as the collecting center because there we have all the files of all meteorological data available.

It would be a pity if such new data would not also be available at the same office, the same bureau, where probably an absolutely unimaginable amount of valuable information is available and would be available to anyone, private individual or an organization. Any meteorologist in the country or abroad could have the information available.

Senator ANDERSON. Do you think the Weather Bureau has that information now?

Mr. NEUBERGER. No. I suggest that the United States Weather Bureau should be, at least, the central depository. The cloud-seeding experiments, I believe, should actually be deposited with the United States Weather Bureau where, naturally, everyone would first look if he wished to have that information.

Senator ANDERSON. I am sure that a lot of us would be glad to have it there. If there were just some one place that one could go and see it, but there is no place now, and that is why legislation, in

my opinion, has become necessary. It is impossible to find out what anyone is doing.

Thank you very much. I hope, Dr. Hosler, when you get a chance—you have not been here all the way through on this—that you will go over the testimony that has heretofore been given and give the committee your suggestions. We would like to have you analyze the testimony given, if you have an opportunity to do that.

Mr. HOSLER. Yes, sir; I will be glad to do that.

(Subsequently the following statement was submitted by Dr. Hosler:)

MARCH 23, 1951.

Mr. MILLS ASTIN,
Chief Clerk, Committee on Interior and Insular Affairs,
Senate Office Building, Washington, D. C.

(Attention: Subcommittees on Interior and Insular Affairs, Interstate and Foreign Commerce, and Agriculture and Forestry.)

DEAR MR. ASTIN: In accordance with Senator Anderson's request, made during the weather-control hearings on the morning of March 19, I herewith submit a brief statement containing my evaluation of, and recommendations based upon the testimony heard before the above-mentioned committees.

In view of the testimony it is quite apparent that weather-control legislation is necessary. The necessity arises as a result of public interest in recently revived weather-control experiments and rainmaking projects. The public and the Government agencies, that serve the public, have a right to know the true potentialities of weather control.

There is no doubt that supercooled clouds can, under certain conditions, be caused to change to ice crystal clouds by "seeding". There is, however, disagreement among authorities as to the exact mechanism behind this cloud modification. Furthermore, great differences of opinion exist as to the extent to which weather can be influenced, and especially as to the efficacy with which precipitation can be caused, augmented, or prevented by seeding. Those who claim appreciable effects of seeding upon rainfall, base their claims upon experiments in which clouds were seeded and rain was subsequently observed to fall. Those who are not convinced of the effect of seeding upon rainfall, point out the fact that since seeding is successful only in those cases where rain might be expected anyway, we cannot establish whether the rain fell because of seeding or from natural causes.

The film shown on Monday afternoon demonstrated quite well the reason for the existing controversy. In this case, a cloud, located over a mountain, was seeded, and rain fell. A meteorologist would recognize this fact. It is common knowledge, that on a summer day with cumulus formation, the most likely place for shower development is over a mountain peak. Thus the meteorologist would be inclined to reason that the lift of unstable air over the mountain caused the shower, especially since the seeding agent must have drifted with the wind (indicated by the movement of the surrounding clouds) during the entire period shown, whereas the rain cloud remained in the same spot over the mountain for several hours. It is still a fact that the shower followed the seeding, but it is quite difficult to prove that the shower would not have occurred in the absence of seeding. In general the effect of cloud seedings performed thus far cannot be established with certainty because of the omission of an adequate experimental design which would lend itself to statistical treatment.

All witnesses appear to agree that, first and foremost, an extensive program of coordinated research should be sponsored by the Federal Government. This need is given recognition in all three bills under consideration, a fact that is to the credit of their authors. A particularly thorough plan for research was presented in the testimony of Mr. Bennett.

Witnesses also agree that this research will be aided if some agency has firsthand knowledge as to the location, time, type, and extent of all rain-making attempts. This is particularly necessary because, at present, we do not know the extent to which local experiments may affect neighboring or distant areas. Power to control the design of such experiments would be essential in order to evaluate their outcome. This control should embrace all attempts at seeding regardless of the material used, since there are a multitude of substances which may be

effective and the extent, to which each of these seeding substances may affect widely separated areas, is unknown.

For the protection of the public, both from the possible results of the experiments, and from unscrupulous operators making false claims, licensing of operators according to some professional code or qualifications is desirable. The American Meteorological Society already has a complete list of all professional meteorologists in this country and their qualifications. This organization, through its extensive membership here and abroad, has been largely responsible for the development of experimental meteorology and cloud physics in recent years. Logically, it should be the function of this society to formulate such standards for licensing as would be necessary, and to adjudge the competence of applicants for licenses.

While it has been advocated that a program of research and control be vested in a new and separate agency, or some individual existing agency that is greatly concerned with weather or water supply, testimony indicates that all interested agencies would be satisfied no matter what organization was primarily responsible, so long as their needs and interests received consideration. It appears then that an organization centered in the United States Weather Bureau, with policies established in collaboration with an interdepartmental advisory board as outlined in bill S. 222, could well administer a program of research and controls similar to that suggested by all three bills. The use of facilities and personnel already available for supervising research, and for the collection and dissemination of weather information, would avoid not only delay in carrying out the program, but also unnecessary duplication of functions and expenditure of public funds. In view of the pressing and varied needs for specific information relative to weather control, it is essential that representatives from the most interested Government departments, such as Agriculture, Interior, and the military, should be members of any policy-making or research-directing agency established. This would tend to keep the immediate needs and goals before the research and control group, and the immediate interests of the public would not be eclipsed by the magnitude of the long-range research program that must be undertaken.

If it should be found that weather control will be of no value to specific areas or interests, the sooner this is established, the better. If research demonstrates that weather controls are impossible on such a scale as to make them practical, or should such controls be found to be extremely limited in application, then no special committee or commission would be necessary to continue restrictions, and the program of academic research could continue under the administration of the Weather Bureau. On the other hand, upon demonstration of the practicability of weather controls on a scale which may cross State or National boundaries, then the establishment of an independent organization, similar to that proposed in bill S. 222, would be necessary.

Respectfully submitted.

CHARLES L. HOSLER.

Senator ANDERSON. Mr. Fox. Mr. Fox, will you identify yourself, please.

STATEMENT OF BENJAMIN FOX, SUPERINTENDENT OF ENGINEERING AND DESIGN, SHIPBUILDING DIVISION OF THE BETHLEHEM STEEL CO., QUINCY, MASS.

Mr. Fox. My name is Benjamin Fox. I am here at the invitation of the committee. I am superintendent of engineering and design for the Shipbuilding Division of the Bethlehem Steel Co.

My job is this. I am in charge of the design of ships and machinery, and in that capacity we have a lot to do with evaporators, originally Navy work and now on all ships. My own experience in evaporators dates back to about 1913 or 1914, and in 1931 I participated in a new development which set a new trend both in the Navy and 10 years later in the merchant marine. I feel that I have knowledge of the art and I am here to help with that.

I did present a statement. I sent it in by mail. A great deal of the testimony that has already been given, particularly by Professor

Sherwood, is so similar to what I have said that I think I can spare you all of that and rather read you an abstract, if I may.

Senator ANDERSON. Yes, indeed, Mr. Fox. That statement will be included in the record at this point.

(The prepared statement submitted by Mr. Fox is as follows:)

STATEMENT OF BENJAMIN FOX

Draft for testimony on S. 5, in reference to production of fresh water by distillation from sea water.

INTRODUCTORY

In the present state of our knowledge, the production of large quantities of fresh water from sea water is practicable only through distillation. This requires the application of heat and a corresponding consumption of fuel; nearly all of this heat is used in vaporizing the sea water but a minor portion is required for developing the power to operate pumps and similar accessories. While any of the common fuels could be used the numerical values in these notes are, for convenience, based on oil fuel derived from petroleum.

In discussing the performance of distilling plants it is convenient to use, as a measure of fuel efficiency, the ratio of pounds of fresh water made to pounds of fuel consumed. This ratio varies widely with the type of plant and the manner in which the equipment is integrated with other activities, such as the propulsion of ships or the generation of power.

In those rare cases where the heat required for distillation is a waste product of another activity the fuel cost for vaporizing the water is zero; and, since the power required is a relatively small factor, the total fuel cost per pound of fresh water is very low and the fuel-to-fresh-water ratio is correspondingly high. This fortunate combination of conditions is rare and cannot be a factor in the problem under discussion.

On shipboard, where sea-water distillation has had its principal application, the heating medium is usually steam and the fresh-water-to-fuel ratio usually ranges from about 25 to about 75 depending on the complexity and the cost of the distilling plant and on the manner in which it is tied in with the propulsion plant. A ratio of about 50 would be considered typical of excellent practice.

A type of plant is available in which the heat required is supplied by compression of vapor through mechanical or electrical power rather than by direct transfer from steam. This type may afford fresh-water-to-fuel ratios as high as 200; and it has been applied on shipboard and elsewhere in large numbers. On ships it is usually limited to very small capacity (up to 2,000 gallons per day) and to installations where there is no adequate boiler plant for steam. Where ample quantities of steam can be made available the steam type has been employed rather than the compression type, because the disadvantage of lower fresh-water-to-fuel ratio is more than offset by decreased complication and maintenance.

In any project for making large quantities of fresh water by distillation from sea water the first requirement is obviously the proximity of the sea, because pumping for any considerable distance would be prohibitive.

A second requirement that is of vital importance is that the fuel efficiency—i. e., the fresh-water-to-fuel ratio—shall be the highest that is practicable. Just as an extreme illustration it can be shown that, with present fuel efficiencies, if we wanted to substitute made water for the whole of our current national consumption of fresh water, we would have to expend fuel equal to the whole of our current national consumption of petroleum oil—that is, all the oil fuel that is now used for every purpose including heating, power, railroads, ships, automobiles, etc.

PRESENT STATE OF DEVELOPMENT

Present-day successful marine distilling plants, heated by steam, vaporize the sea water in a type of evaporator that is generally described as "low pressure, submerged tube." Low pressure means pressure below atmospheric—i. e., vacuum—and is employed because it is associated with relatively low temperatures (below 212° F.) and consequently reduced scale formation. Submerged tube means that the heating surface consists of tubes surrounded by sea water and carrying heating steam inside. Some of the salt deposited out of the sea water settles on the outside of the tubes as a scale and must be removed more or less frequently in order to permit the heat to continue flowing through the walls of the tubes.

Distilling plants of this type have been built from 4,000 gallons per day (17 tons) up. The largest are those installed on the new export passenger liners *Independence* and *Constitution* constructed at Quincy. There are two units on each ship and each is rated at 120,000 gallons per day (500 tons). This capacity represents about the highest that should be built in the submerged tube type for shipboard use; anything substantially larger would probably present prohibitive problems of scale removal. In shore applications also the difficulties of scale removal will impose a sharp limitation on the capacity of individual units. More units for a given output usually entails more total cost.

A more recent development is the so-called low-pressure flash type in which the salt water is within the tubes instead of outside. It is heated in the tubes, without boiling, and the vapor is formed by reduction of pressure after the heated water leaves the tubes. Because of the absence of boiling, relatively little scale is formed in the tubes and this scale is much more easily removed than in the submerged tube type. The reason for mentioning this development is that this principle can be employed with no serious limitations on size or output of unit. A 10,000 gallon per day plant has been in service at sea for about 3 years with gratifying results. Preliminary studies have been made for a plant with a fresh-water output of a million gallons per day (4,150 tons).

APPLICATION TO SHORE INSTALLATIONS

In the present state of our knowledge the principal types of installations that could be considered for producing large quantities of fresh water ashore, in coastal areas, by evaporation from sea water, are as follows:

In combination with the generation of electric power by steam turbines

In this arrangement the steam supplied by boilers produces electrical energy by means of turbines and generators and then provides heat for the vaporizing of sea water. This is not a case of using waste heat and thereby getting the distillation for nothing. The total fuel burned to accomplish the dual purpose of electric generation and distillation is greater than the fuel that would be required for producing the electrical energy alone and the distilling plant must be charged with the difference. Roughly the most economical combination gives a fresh-water-to-fuel ratio of 125. At $1.90 per barrel of fuel oil the fuel cost works out to 35 cents per thousand gallons of water or 8½ cents per ton.

Unfortunately there is the inherent limitation that the amount of fresh water that can be so made is related to the amount of electrical energy being produced. For the combination associated with the fuel figures mentioned above the fresh water output would be 2.6 gallons for each kilo-watt hour of power generated. In a typical community the per capita consumption of electric power is about 3.25 kilowatt-hours per day and the correspondingly available fresh water would be 8.5 gallons per day per person, which is perhaps 8 percent of present consumption requirements.

By accepting a substantially higher fuel cost the quantity of fresh water available for each killowatt-hour of electrical output might be doubled. In any case this type of distilling plant would require extensive modifications to existing power plants.

It therefore appears that the combination of distillation with electric power generation could be attractive only in those isolated cases where the per capita electric power consumption is many times greater than normal, due to the presence of unusually large industrial consumers of electricity.

It is possible, of course, to divorce the distillation from electric power generation, and from the associated limitation of capacity, by providing a boiler plant to serve the evaporators direct. This entails the expenditure of about two-thirds more fuel, i. e., about 60 cents per thousand gallons or 15 cents per ton for the fuel cost of making the fresh water.

A more promising solution is now under development. It involves the combination of two principles previously mentioned, namely, vapor compression and flash evaporation. These are applied in a manner that avoids the complication and maintenance associated with the present vapor compression type plants. The fresh-water-to-fuel ratio obtainable, and the resulting fuel cost, now appears to be very nearly the same as in the first alternative described above where evaporation is accomplished in combination with the generation of electric power, i. e., about 35 cents per thousand gallons of fresh water. This solution has the very great advantage that the fresh-water-making capacity is completely independent of the generation of electric power.

The approximate cost figures cited above relate only to the fuel consumed to produce the fresh water. They will not be very different whether this fuel is coal or oil. However, there are additional costs which comprise investment charges, labor, and administration. These will vary with the type and design of plant adopted, and with regional and economic conditions. A lot of study is needed before one can predict closely the total costs for making fresh water from sea water in a particular coastal area; but enough has been done to indicate that, in many cases, this total cost will be less than $1.60 per thousand gallons (40 cents a ton), with the probability of substantial reductions upon further development. This is not as cheap as getting the water for nothing but it could very well be much cheaper than transporting it from where you can get it for nothing to where you must have it.

CONCLUSION

There is enough background of experience in the Navy, and more recently in merchant ships, to prove that it is entirely feasible to produce, by distillation from sea water, very large quantities of fresh water in every way suitable for all human and industrial use. It is quite likely that great improvements in processes and reductions in cost can still be made. If the national interest may require that these very large quantities be produced it is of the utmost importance that there be instituted a program of intensive development and research to improve the processes and, particularly, to reduce the fuel and other costs.

Mr. Fox. My statement is limited to the production of fresh water by distillation from sea water. It is not intended as a blanket endorsement of the various provisions of S. 5, as there are many points on which I have no opinion.

The production of fresh water by distillation of sea water has long been an essential process on naval vessels. Improvements in the last decade or two have led to the extension of this practice into merchant ships so that practically every new, important ship is equipped to make all the required fresh water as needed instead of taking large quantities from shore for the duration of the voyage.

The principle, again, is a more economical ship. I might mention in passing that a ship that 15 years ago would be designed to carry 3,000 tons of water to do for passengers and the boilers, today is designed to carry only 800 as a reserve in case of a casualty, and the rest is made as they go, three or four or five hundred tons a day consumed and made from day to day.

Senator CORDON. What do they do with the solids?

Mr. Fox. They do not ever evaporate it down to the point where it is solid. They just concentrate the brine and throw it away. They take in, let us say, in a typical case 3 gallons of ocean water and throw away 2 gallons of brine and have the fresh water. There are ratios in that type of plant. When you do concentrate the brine, you burden yourself with, at present, an insuperable job of keeping the thing running when you do evaporate down to a solid.

Senator CORDON. Do you see any reasonable possibility in the future of carrying the process through to extraction of solids involved?

Mr. Fox. I would say that the solids that are in there would have to be much more valuable than is known to ever justify the burden that you would take if you evaporated sea water down to solid. Possibly there is some gold in there or uranium, I do not know, but not for the salt.

Senator ANDERSON. What is the Dow Chemical Co. doing on the coast? Are they not getting magnesium out there?

Mr. Fox. I do not know.

Senator ANDERSON. They have a plant on the Gulf of Mexico, financed by the Government in the last war, for the extraction of magnesium from sea water.

Mr. Fox. I think I can clear up my statement. What I meant is that when you are interested in making fresh water, which has been my interest, you do not burden it with the incidental problems of recovering solids. When you do burden it that way, you have an entirely new problem and a different type of plant.

Senator CASE. That is for the amount of water that you would be recovering on board ship for ship use, it would not pay to worry about the solids.

Mr. Fox. No, I do not mean that. In my opinion, the problem would be even more important if you were making much larger quantities of water. The problem of making fresh water is very much different from the problem of concentrating sea water down to solid. On that second problem I have little knowledge.

This general practice on ships is complete proof that fresh water can be made from sea water in large quantities and that it is fit for human consumption and for industrial use. In any project for making large quantities by distillation from sea water, the first requirement is obviously the proximity of the sea, because pumping for any considerable distance would be prohibitive.

A second requirement that is of vital importance is that the fuel efficiency—that is, the fresh-water-to-fuel ratio—shall be the highest that is practicable. Just as an extreme illustration, it can be shown that with present fuel efficiencies, if we wanted to substitute made water for the whole of our current national consumption of fresh water, we would have to expend fuel equal to the whole of our current national consumption of petroleum oil—that is, all the oil fuel that is now used for every purpose including heating, power, railroad, ships, automobiles, and so on.

The fuel cost can be predicted very closely, fairly closely. At present price levels it would be about 35 cents a thousand gallons. The additional costs due to investment charges and operation are not easily predictable. A very rough check indicates that the total need not exceed $1.60 per thousand gallons.

Now, by way of an aside, I made the figures for this thing about a year ago before I ever heard there was any such bill coming up. At that time I arrived at an approximation of $1.19. By the time I was invited or it was suggested that I might attend last June or July, I raised it to $1.40, because something had been happening to our dollar and as of now I have set it down $1.60 for the same reason, but the original figures have not been changed.

In conclusion, it is entirely feasible to produce by distillation from sea water very large quantities of fresh water in every way suitable for all human and industrial use. It is quite likely that great improvements in processes and reductions in cost can still be made. If the national interest may require that these very large quantities be produced, it is of the utmost importance that there be instituted a program of intensive development and research to improve the processes and particularly to reduce the fuel and other costs.

There was one statement that I had here that may be worth repeating. This $1.60 a thousand gallons is not as cheap as getting the water for nothing, but it could very well be much cheaper than transporting it from where you can get it for nothing to where you must have it.

Senator ANDERSON. Thank you. That is very true.

Senator SMATHERS. Yes, indeed; very true.

Senator ANDERSON. Thank you very much, Mr. Fox.

Senator SMATHERS. May I ask just one question? How soon do you think it might be practical for a city on a sea coast and where it does not get fresh water, to operate its own water plant as a municipally owned water plant?

Mr. FOX. It is practical to start this today. There would be no experiment involved at all. You could lay out the job, predict the cost, build it, and it would surely work, but if you spent a very small fraction of that building a pilot plant, you might find a substantial gain due to having done that. In other words, we are where we are, but that is not where we can be if the thing becomes important.

Senator SMATHERS. Other than yourself, you people there at the Bethlehem Steel Co., do you know of any further experimentation that has gone along on this business of extraction?

Mr. FOX. Yes. Experimentation is going along. It is of a minor sort. It is development. It is improvement in the mechanisms and the details which have really accomplished the greatest gains.

Experimentation is going along all the time, but it has been limited to the needs of a ship, and we can start from there and meet certain conditions on land, but we do not have to accept those limitations, and, if there were somebody who would sponsor development, I think that it would be well worth it.

Senator ANDERSON. A very good statement. We do not have to accept those limitations?

Mr. FOX. No. We have not accepted them. The art today is probably 10 times better than it was 20 years ago, through the needs of the marine service. What I mean by that is that you can get a gallon of fresh water for a tenth the weight and space of equipment, which governs things on a ship, than you could, let us say 20 years ago, and also the art has progressed to the point where the purity of the water is infinitely superior to what it was 20 years ago.

I will cite some tests made by the Government's Public Health Service to demonstrate that. They wanted to be sure that they could get highly contaminated water, put it through an evaporator to see what happened, water that was bacteriologically contaminated. They tested our contaminated docks and said there are some worse than that, so they said why not take it out of the sewage system, and they did.

They took the water out of the sewage system and put it through the evaporator and found it free of bacteria, which is what they were looking for. This was not our test; it was the test of the Public Health Service.

On the basis of that test and tests like it, the authorities have swung over completely to the fact that water made by evaporation from sea water under certain known conditions, regulations, controls, is better for all purposes than ground water, much better for boilers and much better for the guts.

Senator ANDERSON. Thank you very much.

Senator SMATHERS. That is most encouraging.

Senator ANDERSON. Senator Case, I believe, has two witnesses here, and I am going to ask him to have them come forward.

Senator CASE. Mr. Marshall and Mr. Ingvalson.

Senator ANDERSON. We are glad to welcome you both here. Senator Case, will you present them.

Senator CASE. Mr. Chairman, closest to you is Mr. Harry Marshall, of the Marshall Flying Service, of Rapid City, S. Dak., and next to him is Mr. E. L. Ingvalson, managing editor of the Rapid City Daily Journal.

I might say by way of introduction that these are the two persons whom I interested in our rather crude experiment which was performed in western South Dakota last July. I had been reading something about this matter of seeding clouds with dry ice more than I had the silver iodide method, and Mr. Marshall was interested in the subject so I arranged with him to make a couple of flights, and Mr. Ingvalson went along. How crudely we operated can be shown by the fact that we carried the dry ice in a little carton and Mr. Ingvalson took a teacup and threw it out the window as we went over the cloud, but we got rather interesting results;

I think probably the principal value of having them say anything here—they have been very interested listeners—will be to show how this thing is working in the grass roots, in the Great Plains area.

As you know, Mr. Chairman, from your contact with the Department of Agriculture, Secretary before, and since, the Government has spent large sums of money through the Resettlement Administration and the Farm Security Administration to try to make more secure the production of crops and the growing of cattle in the area of marginal rainfall, that which is not quite dry enough to justify full-fledged irrigation and yet which is not regular enough in its rainfall to insure the growing of crops regularly.

In fact, from your own boyhood and young manhood in South Dakota you know the problem there directly. I should say that these gentlemen intended to fly in here yesterday but they ran into a blizzard in Minnesota and were flying most of the night to get here. We did not have an opportunity to confer this morning. I think possibly if I asked two or three questions they might bring out a point or two.

Senator ANDERSON. Whatever you want to do, Senator Case, you go ahead and do. We are very happy to have you both in here even under such trying circumstances because it is important to know what can be done in the small way to test this out and see if you can improve the moisture pattern in some of these arid States.

Senator CASE. I would like to ask Mr. Ingvalson first what he can tell us either by personal knowledge or by observation as the managing editor of the principal paper in this area, of the interest of the ranchers and farmers in this kind of an activity.

STATEMENT OF E. L. INGVALSON, EDITOR, RAPID CITY (S. DAK.) DAILY JOURNAL; ACCOMPANIED BY HARRY MARSHALL, MARSHALL FLYING SERVICE, RAPID CITY, S. DAK.

Mr. INGVALSON. Well, there is no question about the interest. If you will pardon me, like Frankie Costello, I have laryngitis. Go easy on the questions.

There is no question about the interest, and Harry here will verify that, because we, in newspaper parlance, did not play it up too much to begin with. We did not build it up. We wanted to see what was going to happen first before we said anything about it, and, contrary to some of the testimony that we have heard so far, Harry and I

thought that we made rain. Then I really went to town on it in the paper, and that started the flood of calls.

I was getting them, Harry was getting them, and they were directed to Senator Case likewise. That is all it took in our area, and that covers approximately half of South Dakota—the western half.

Senator ANDERSON. You are referring to the area from the Black Hills to the Missouri River?

Mr. INGVALSON. That is the territory. The inquiries came by phone, and we were getting them by telegraph. We got a great many letters. They all wanted to know how good was it and what could we do about doing the same thing over their little section of the country.

Senator CASE. Are you familiar with the sign-up recently completed in Wyoming immediately west of the Black Hills, with representatives of the Krick organization?

Mr. INGVALSON. Yes.

Senator CASE. Do you know the size of the area that is being contracted there?

Mr. INGVALSON. That ran into several million acres and they were going to spend almost $100,000, I think. As I recall it, they were going to assess the ranchers per acre, and there is an indication of interest. The ranchers have already kicked in the dough.

Senator CASE. My understanding is that in the area immediately west of Belle Fourche, as he has indicated, where we had this telegram from the other day, the ranchers have actually kicked in over $93,000 and they have signed a contract for the seeding over an area of about 16 million acres, that is, for this coming summer. Ninety-three thousand dollars for voluntary contributions evidences interest in a very concrete way.

Mr. INGVALSON. They have already paid in the money to the Krick organization.

Senator CORDON. How long had it been since it had rained in that area?

Mr. INGVALSON. You mean on our particular experiment? It has not rained—well, you caught me short—for, I would say, 5 weeks at least—at least 5 weeks.

Senator CORDON. What had been the climatic condition with reference to its being clear or cloudy over that 5-week period?

Mr. INGVALSON. Mostly clear.

Senator CASE. Harry, I think you have been following the weather a little bit more before you went up there, and perhaps those questions could be more appropriatedly directed to you.

Senator CORDON. I just wanted to get the picture of the seeding itself and the weather conditions before, during, and after.

Senator ANDERSON. You could not do anything until there were cloud formations, could you?

Mr. MARSHALL. That is correct.

Senator ANDERSON. How long did you have to wait until there were?

Mr. MARSHALL. Fortunately, we did not have to wait at all. We started in immediately. The conditions were right.

Senator CORDON. What were the conditions?

Mr. MARSHALL. In Rapid City, the air base there has a radiosonde beam. We are very fortunate, since there are so few of them in the

United States, and by that we were able to tell the exact humidity and exact temperature at different altitudes, which, of course, is advisable to know before you start seeding a cloud.

Senator CORDON. Tell us about the humidity, and so forth.

Mr. MARSHALL. That is what I am going to explain. Our first trial, the humidity was 74 percent at 13,000, which is the freezing level, so we got our rain.

Senator CASE. What, actually, did you do, Harry?

Mr. MARSHALL. We just started putting out the dry ice.

Senator CORDON. Let us get the picture of it. Was this a solid cloud formation above?

Mr. MARSHALL. No. It was a cumulus type.

Senator CORDON. Fairly well scattered or fairly heavy?

Mr. MARSHALL. Very much scattered, and they were all of the same structure and nature, and did not look like any of them were going to rain. It was plain cumulus.

Senator CORDON. How long had they been over there? Had they come just recently or had the area been clouded for some time?

Mr. MARSHALL. They form over the Black Hills area most every afternoon.

Senator CASE. There is a certain time during the afternoon when one is likely to see clouds form over the mountains.

Senator CORDON. Did this experiment take place in the area where they form or out some distance where they drifted?

Mr. MARSHALL. Approximately 30 miles east of where they formed, I would say.

Senator CORDON. That would be out of the Black Hills and on a level?

Mr. MARSHALL. That is right; yes, sir.

Senator CASE. Harry, at what altitude did you get over the cloud?

Mr. MARSHALL. Approximately 19,000 feet mean sea level, which would be about 16,000 feet.

Senator CASE. Is that where you started?

Mr. MARSHALL. Not over the cloud. We started right at the top of the cloud itself.

Senator CASE. When you started at the top of the cloud what elevation did you have?

Mr. MARSHALL. Around 19,000; 19,500 I believe it was.

Senator ANDERSON. What did you do? You dumped out dry ice?

Mr. MARSHALL. Yes, sir.

Senator CASE. What happened?

Mr. MARSHALL. The top of the cloud seemed to dissipate off. It seemed to flatten out, and we put it out at the rate of approximately a pound per mile. We kind of had it timed. We were not just going to throw out a lot.

Senator CORDON. Did you circle this cumulus cloud?

Mr. MARSHALL. We flew through it, sir, over the top of it and then through it.

Senator CORDON. What area would you say it covered—the area of the cloud itself?

Mr. MARSHALL. I would say it was a cloud about, not over, 2 miles long.

Senator CORDON. Did you make several runs through it?

Mr. MARSHALL. Yes, sir; at different altitudes, down to the freezing level.

Senator CORDON. You must have had a rough trip through a cumulus cloud.

Mr. MARSHALL. It was a little rough, yes. It was not a cumulus nimbus. It was not too bad.

Senator CASE. The particular cloud that you went into, did it show any particular difference from the other clouds that were drifting that day?

Mr. MARSHALL. Thank you for bringing that out, Senator Case, but the clouds appeared all to be alike, and we did not pick on any one cloud thinking it might rain before the other one. They all looked alike to us.

Senator ANDERSON. What happened when you seeded it?

Mr. MARSHALL. The top of the cloud dissipated off and then the bottom started forming a cloud, and within about 22 minutes we were flying in a good rainstorm underneath that very same cloud.

Senator CORDON. How long did the rain last?

Mr. MARSHALL. It started to get dark on us and we flew back toward Rapid City, but we flew in the rain for at least a half an hour.

Senator SMATHERS. May I ask, did any of the other clouds start raining?

Mr. MARSHALL. No, sir.

Senator SMATHERS. Just that one cloud in which you put the ice?

Mr. MARSHALL. That is right.

Senator CORDON. That was only 2 miles across. You flew in the rain how long?

Mr. MARSHALL. We flew back and forth and the cloud expanded out when it started to rain.

Senator CORDON. To what extent?

Mr. MARSHALL. The area of rain, I would say, was about 3 miles wide.

Senator CORDON. From information which I assume you subsequently acquired, do you know whether there was rain from any of the other cumulus clouds in that section, or not?

Mr. INGVALSON. Not a drop.

Mr. MARSHALL. Not a drop; no, sir, within 1,500 miles, I would say.

Senator ANDERSON. How often did you do this?

Mr. MARSHALL. I have tried it five times.

Senator ANDERSON. What has happened each time? Has it rained five times?

Mr. MARSHALL. No, sir.

Senator ANDERSON. It rained once?

Mr. MARSHALL. It rained the first time. We got snow the second time, which evaporated; that is, it dissipated into rain and evaporated. Conditions were not right. We were just experimenting. We tried it in the Bison area—that is north of Rapid City—and we got rain three times there. So, we actually got moisture all five times.

Senator ANDERSON. I think that is pretty interesting.

Senator CORDON. In these five times, what happened in surrounding areas where there were like clouds? Was there any precipitation?

Mr. MARSHALL. In one particular case it did rain about 20 miles away from the particular cloud that we had seeded.

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Senator CORDON. Was the rainfall there comparable to that which fell from the cloud you had seeded?

Mr. MARSHALL. It was much more. It was a cumulus nimbus cloud, a thunder-type cloud. It rained before we even started in on the other one.

Senator CASE. What was the reaction of the ranchers?

Mr. MARSHALL. Very enthused.

Senator CASE. Did the ranchers in the area think that you had produced rain?

Mr. MARSHALL. We landed at one particular ranch—I do not recall the rancher's name offhand; I do not have it with me—and we got his signature to the fact that it rained on his place, and so on. I had one particular rancher with me one time when we were making it rain; so that he knew for sure.

Senator CASE. I think the point is pretty well made, Mr. Chairman, that whether we do anything or not the interest that is demonstrated in experiments like that mean that that is going to go on unless in some way somebody puts up a bar and says, "You cannot do it."

You used just dry ice?

Mr. MARSHALL. Just dry ice.

Senator CASE. You did not go into the use of silver iodide. There has been interesting testimony here to suggest that the silver iodide is a much more complicated problem; that the use of carbon dioxide might be handled by licensing, but that the silver iodide produces effects which might be delayed or carried over to some distance from where the operation takes place, but that in seeding of specific cumulus clouds with dry ice you have a much more localized result.

Senator ANDERSON. I think that is a very important point: that there is interest. People wanted you to come there and do it, and they were happy that you did try it.

Mr. MARSHALL. I might add this: A number—I guess you would call them county agricultural advisers—have written me since, and I have letters requesting that I sit with them at meetings and prepare cost analyses of what it would take to make rain in their area.

I have answered the letters and everything, but I have not actually given the cost due to the fact that, as the lawyer who sat here a while ago was talking about the suit problem, I do not care to get involved.

Mr. INGVALSON. I might add something on that liability thing. I have not had any direct letters, but I have had several questions, half humerous and half serious, about taking somebody else's rain away from them, and that has been going on ever since we did this last summer.

Senator ANDERSON. I do not think it is nearly as much the question of taking someone else's rain as by overseeding, spoiling it for everybody, and that could happen, but that will not happen with dry ice.

As long as you are seeding with the dry ice, I do not think anybody is going to argue with you.

Senator CASE. Just one other question about that second experiment where you got the snow. Was your humidity the same as it was the day before?

Mr. MARSHALL. No. It was lower, about 40 percent lower at the freezing level, which was about 14,000. We also found that smaller amounts of dry ice were much better than larger amounts.

Senator CASE. That smaller amounts worked better?

Mr. MARSHALL. Yes.

Senator CASE. In other words, at first you thought a little is a good thing but more is better, but it was not?

Mr. MARSHALL. We used 100 pounds, as I recall, the first time. We found out that 1 or 2 pounds were just as good.

Senator ANDERSON. Thank you very much.

We will adjourn until 3 o'clock this afternoon, if the members of the committee want to see the General Electric film.

Senator CASE. Mr. Chairman, might I ask permission to place in the record a couple of newspaper accounts of some of those experiments?

Senator ANDERSON. Without objection, that will be done.

(The newspaper accounts referred to appear below:)

[From the Aberdeen American News, Aberdeen, S. Dak., March 21, 1951]

HE TRIED IT—SOUTH DAKOTA EDITOR SURE RAIN MAKING WORKS

WASHINGTON.—A South Dakota editor told a Senate subcommittee Monday he is sure you can whip up a rainstorm by artificial means because he did it himself.

E. L. "Paddy" Ingvalson, managing editor of the Rapid City Daily Journal, told the Senators he did it with some dry ice tossed into a fleecy cloud from the window of a high-flying airplane.

"Paddy" says he and the plane's pilot, Harry Marshall, used an empty cottage cheese container to dish out the ice in a flight suggested by Senator Case (Republican, South Dakota).

Ingvalson and Marshall testified before a subcommittee holding hearings on bills that would put the Government in the business of sponsoring and controlling experiments to make rain by "seeding" clouds with dry ice and other compounds.

Both South Dakotans said they are convinced dry ice can nudge clouds into turning on rain. There is considerable disagreement on this theory among scientists.

Dr. Charles L. Hosler of the Pennsylvania State college said at the same hearing: "Seeding of clouds at the present time is more or less like prayers—it's a matter of faith."

He contended there's no way of actually proving, right now, that seeding itself does the trick.

But Editor Ingvalson had this personal account:

"It hadn't rained in South Dakota for 4 or 5 weeks when we made our test last July and the weather forecast for that day said nothing about rain.

"When we went up to about 19,000 feet there was no solid cloud mass, just a batch of scattered clouds.

"We picked one, and sprinkled out about 75 pounds of ice—about a pound to a mile, back and forth and all around in a belt about 3 miles wide and 15 miles long.

"The cloud was fleecy white when we started, but it started graying up, and about a half-hour after we finished sprinkling the ice it started to rain.

"Meanwhile, all the other clouds around us, anywhere from 5 to 15 miles away were still all white and fleecy.

"The weather office at Rapid City said that if it was going to rain it would rain anyway.

"But, when you take one cloud, seed it and get rain—and you don't seed other clouds, and they don't produce rain—that's enough for me. I'm convinced."

Ingvalson and Marsball said their rain occurred near the Cheyenne River, about 40 miles east of Rapid City, and that when they got back and told about it their friends in the Weather Bureau were still unconvinced.

But Ingvalson found several ranchers who said you're darned right it rained.

Did Ingvalson present this rebuttal evidence to the weather man?

"No," he said, "I just put it in my story."

[From the Aberdeen American News, Aberdeen, S. Dak., March 28, 1951]

SERIOUS STUDY GIVEN RAIN MAKING

Senator Francis Case, who promoted some rain-making experiments in western South Dakota last summer, is following through in his customary thorough manner.

He arranged for E. L. Ingvalson, of the Rapid City Journal, who seeded cloud formations with dry ice, and Harry Marshall, the pilot to relate their successful experiences to the Senate Interior Committee and is pleased with the impression they made in Washington.

Senator Case is hopeful that rain making may become a scientific accomplishment.

And if that can happen he is satisfied that hail can be dissolved before it damages farmers' crops and lightning can be dissipated before it starts forest fires.

South Dakota and North Dakota are certainly States that will have a great deal to gain from such developments.

Rain at the right time makes or breaks crops. Hail and lightning, of course, are always a threat. Their elimination would be comforting.

[From the Chamberlain Register, Chamberlain, S. Dak., March 15, 1951]

RAIN-MAKING PLANS IN BRULE COUNTY TO BE DISCUSSED TUESDAY

A meeting will be held on the rain-making project in the Pukwana City Hall next Tuesday evening at 8 p. m. This is the meeting which was announced in a previous issue of the Register, and will be the one to decide whether or not this project will be undertaken during the coming season.

Promoters of the project which number many enthusiastic farmers and businessmen are urgently requesting all to attend. More of these groups are invited, and from the interested people attending the last meeting, it would well be worth anyone's time.

"Rain making" meetings held in the last 10 days in Plankinton, White Lake, Chamberlain, Wessington Springs, and Kimball have resulted in the formation of the Central South Dakota Weather Improvement Association embracing the area comprising Aurora, Brule, Buffalo, and Jerauld Counties. The purpose of the association is to determine means of increasing rainfall by artificial cloud "seeding" techniques in the four counties.

At meetings held throughout the area, Kenneth C. Raetz, Midwest regional director of the Water Resources Development Corp., discussed the pros and cons of weather modification by means of "seeding" storms with silver iodide crystals emanating from surface generators. This technique has been used successfully by WRDC on over 100 million acres from Washington to the Texas Panhandle, producing increases in rainfall from 100 percent to as high as 500 percent.

At the present, the Water Resources Development Corp. has the entire State of Colorado and two-thirds of New Mexico under contract for 1951 seeding operations.

"The success of our operations in semiarid regions like New Mexico indicates that equally successful operations would be accomplished with even greater ease because normal rainfall in South Dakota is considerably greater," Raetz explained. "We do not make rain, we increase it. Hence, where there is a greater meteorological opportunity as is evidenced by the increased amount of natural rainfall in South Dakota our base for success is broadened proportionately."

PRELIMINARY COST $4,200

The cost of the four-county preliminary survey is $4,200, with the estimated cost of the seeding project being from $50,000 to $60,000 for the season, depending on the acreage involved and duration of the seeding operations. Average cost per acre is expected to be in the neighborhood of 6 to 10 cents for the season.

Lloyd Thomas, Plankinton, acting chairman of the group, emphasized the need for speedy action. "If we are to gain the benefits of cloud seeding this year, the survey sum must be raised within 2 weeks. It will take WRDC 30 days to complete the survey, which means that we have to act now. Pledge forms are being distributed. It has been agreed that no contribution be over $100, and all money pledged will be given full credit against the acreage allotment for the rain-increase project. It will take only a hundred leading farmers in this area to ad-

vance $42, to insure the program going over the top. Returns now in my office show that we're past the halfway mark right now."

[From the Daily Argus-Leader, Sioux Falls, S. Dak., March 23, 1951]

Work Started on Rain-Making Program in South Dakota—Brule County Farmers Pledge $1,200 for Meteorological Survey

Pukwana, S. Dak., March 23.—The start of a rain-making program this year in the general area covered by Brule, Aurora, Jerauld and Buffalo Counties virtually was assured here this week when about 50 Brule County farmers pledged more than $1,200 to put the drive for funds for a meteorological survey over the top.

As explained by Lloyd Thomas, Plankinton, chairman of the Central South Dakota Weather Improvement Association's temporary board of directors, no definite decision will be made as to whether the actual rain making will start until after the survey has been made.

In a telephone call from Kenneth Raetze, field man for the rain-making firm, Thomas was told it is believed by the firm that rainfall can be increased in the area by 5 or 6 inches from April to September.

[From the Belle Fourche Post, Belle Fourche, S. Dak., March 16, 1951]

Ninety-three Thousand Five Hundred Dollar Rain Project Approved at Gillette

The contract has been signed, the money has been collected. Now farmers and ranchers of an eight-county area in northeastern Wyoming and southeastern Montana are going to wait for rain.

The go-ahead signal for the first widespread rain-increasing project of the region was given at Gillette yesterday afternoon when the Powder River Weather Resources Corp. was officially incorporated and a contract was signed with the Water Resources Development Co. of Pasadena, Calif., for rain-increasing activities over 16,164,444 acres.

Under provisions of the contract the Pasadena firm will start cloud-seeding operations April 15 and are to seed every feasible cloud formation over the area until October 1, unless the Powder River group requests otherwise.

The project is a $93,500 affair, and William W. Smith, Gillette, chairman of the Powder River Corp., says all the money for the undertaking has been collected on the basis of per-acre payments.

Payments will be made to the California firm in three blocks. A down payment was made yesterday following the signing of the contract, but the amount was not disclosed. Another payment is to be made when the cloud seeding gets under way and $15,000 will be withheld until the project is completed, Smith said.

Counties affected by the project will include Sheridan, Johnson, Campbell, a portion of Converse County, Crook, Weston, Niobrara, in Wyoming, and Powder River in Montana. Several ranchers on the southern and western borders of Carter County also have joined the project.

The Water Resources Development Corp. already is making a weather survey of the area.

[From the Sundance Times, Sundance, Wyo., March 22, 1951]

County Ranchers Join Rain-Increasing Project—Area To Pay $10,565 Share—Operations To Start April 15 if Needed

Crook County is assured of artificially increased rainfall this spring and summer, if the methods of weather research experts prove effective.

Ranchers and farmers in the county signed, March 15, to participate in the rain-increasing activities of the Powder River Weather Research Corp. at a meeting in Gillette. Eight northeastern Wyoming counties and Powder River County, Mont., have organized to form the corporation.

The group signed a contract for $93,500 with the Water Resources Development Corp. of Pasadena, Calif. Operations under the contract will begin April 15, and continue until October 1.

The contract represents the largest single initial project ever signed by the California firm. It will cover 16,164,444 acres in Crook, Weston, Campbell, Converse, Sheridan, Johnson, and Niobrara Counties in Wyoming and Powder River County, Mont.

Crook County's share in the contract is for $10,565.50 plus $300. The $300 is tentatively the county's share of the operating expenses of the Wyoming corporation.

During the period of the contract, the California firm will furnish materials and services needed for the artificial increase of rainfall, subject to the orders of the board of directors of the Wyoming Corp.

The Wyoming group was an association before it filed articles of incorporation with the office of the secretary of state after a meeting, March 7, in Gillette. Orville Harper, Crook County rancher near Beulah, has been named to the board of directors of the new corporation as Crook County's representative. Each of the counties in the corporation has one voting representative on the board of directors.

Bill Smith of Gillette has been named president of the board, voting only in case of ties. Osborne Pemberton of Powder River County is the first vice president and Joe Watt, Weston County's representative, with a Moorcroft address, is second vice president. C. H. Davis, the Campbell County director, is secretary-treasurer.

Crook County's decision to join was made at a meeting of the Crook County advisory committee of the corporation March 14, in Sundance. Committeemen from the several parts of the county attended the meeting.

Mr. Harper revealed that many parts of the county have subscribed to the project 100 percent. Funds to pay the county's way in the operation have been solicited on a 1½ cent an acre basis.

He added that the corporation is still accepting money from farmers and ranchers of the county for the project. Checks covering owned or controlled land should be made out to Crook County Rain and sent to the Sundance State Bank, depository for the Crook County committee.

Mr. Harper pointed out that the more money collected would mean less cost of the project to the individual farmer and rancher.

He has also requested that any persons who feel opposed to the rain increasing project in the county or wish to air a grievance about the operation contact him. The Wyoming Corp. has set up an organization to settle such disagreements.

Personnel of the Water Resources Development Corp. has already begun the collection of weather data in the area covered by the contract.

While the northeastern Wyoming project is the largest single initial area ever covered by a rain-increasing contract, the California firm has larger projects contracted during the second year.

Mr. Harper reported that the new corporation went on record as opposing full Government regulation and administration of weather modification. The corporation has sent telgrams to Washington opposing the bill of Senator Clinton Anderson, Democrat, New Mexico, which would put rain-increasing operations under full Federal control. The bill is now in hearing.

Monday night the Redwater local of the Crook County Farm Bureau supported the stand of the corporation. The local passed a resolution asking the Government to withhold controls on rain projects until solutions to any future problem are worked out by weather research men and the type of controls needed be determined.

The resolution will be sent to the State Farm Bureau Federation and relayed to the various Farm Bureau locals in Wyoming for mass consideration.

[From the Deadwood Pioneer-Times, Deadwood, S. Dak., April 1, 1951]

EDGEMONT.—J. M. Tucker of Edgemont has called a meeting for Monday, April 2, to make arrangements for getting rain at Edgemont and surrounding territory.

All interested townspeople and farmers and ranchers are urged to attend the session.

[From the Daily Republic, Mitchell, S. Dak., March 30, 1951]

CSDWIA Is a Permanent Set-up as Officers are Named at Kimball Meet

(By Dick Kobak, Daily Republic city editor)

Kimball, S. Dak.—The Central South Dakota Weather Improvement Association became a permanent organization last night with Harold Willrodt, Chamberlain, as president.

First move of the permanent group was to authorize Lloyd Thomas, Plankinton, who has been temporary chairman, to check the contract with the Water Resources Development Corp., Denver, Colo., for a meteorological survey with a lawyer and to sign it.

Thomas, now the association's secretary by virtue of last night's election, also was authorized to investigate the possibility of forming a corporation.

Meeting last night in the Kimball House lobby were the members of the temporary board of directors named at a series of local meetings in Brule, Aurora, Jerauld and Buffalo counties.

With the temporary board's two main purposes, the dissemination of information and the decision on the meteorological survey, completed, the temporary board voted itself a permanent body.

With Willrodt as president and Thomas as secretary, board members elected H. T. Gerhard, Plankinton banker, to be treasurer, and Frank Jenson, Wessington Springs, and Frank Knippling, Chamberlain, to be vice presidents.

As explained by Kenneth Raetz, regional director of the Water Resources Development Corp., the organization is not bound to carry on business with the corporation after the survey is completed by the corporation's nonprofit subsidiary, the American Institute of Aerological Research.

Providing the survey of weather in the four-county area shows rain-making to be feasible, the association is free to hire any rain-making firm.

Actually the Water Resources Development Corp. cannot make rain but can increase the amount of moisture which will fall in a prescribed period over the target area.

The board passed several motions providing for the operation of the association. Each member of the association, that is, each farmer who pays his acreage assessment for the rain increase, is entitled to one vote.

The board itself was given the power to fill any vacancies on it which might appear, and 15 percent of the total membership can overrule any decision of the board.

Representation on the board will be according to Production and Marketing administration communities which include from two to three townships with one member from each of those districts and one from each town in each county.

Estimated membership of the board under those conditions is about 35, Thomas said.

Raetz told the board members that any local information on weather can be used as an appendix to the contract which presumably will be signed for the firm's rain increasing operations.

The Water Resources Development Corp. seeds clouds with silver iodide crystals from ground generators to increase moisture.

Asked what protection the association would have should legislation be passed by Congress, Raetz replied that the only purpose of Senate subcommittee hearings on the project was to gather all the legislation passed by State legislatures.

"Our corporation had a part in writing the legislation on rain making which now is on the books," said Raetz.

He declared the major purpose of any legislation would be to protect people against "wildcat" operators.

Thomas pointed out that despite criticism by Sen. Clinton Anderson (Democrat, New Mexico), he has invited officials of the National Weather Improvement Association to meet with him on legislation agreeable to all parties.

The secretary said meetings will be held anywhere they are wanted when the campaign for funds to pay the assessment per acre starts. He estimated that 500,000 of the 1.5 million acres in the area will be needed to bring the cost down to 10 cents an acre for the growing season.

Should a second Weather Improvement Association start in Davison, Hanson, Sanborn, and McCook counties, it will have no effect on acreage costs this year, according to Raetz.

Next year, however, if the new association should merge with the first, the merger probably would result in a reduction of the cost for each acre.

[From the Daily Republic, Mitchell, S. Dak., March 31, 1951]

START BOARD TO DECIDE ON RAIN AREA INCLUDING DAVISON

(By Dick Kobak, Daily Republic city editor)

ARTESIAN, S. DAK.—Organization of a temporary board of directors to study the possibility of a rain-increasing project which may include Davison, Sanborn, Hanson, and Miner Counties was started Friday night at a meeting in the Artesian American Legion Hall.

Named to the temporary board of directors were Dan Wendell, Letcher; Walter Cope, Artesian; Francis Dean, Artesian; and Fred Ischen, Fedora.

Other meetings are to be held where interest is expressed in the project. If farmers in the area are interested, organization of another weather improvement association similar to that formed in Aurora, Brule, Jerauld, and Buffalo Counties probably will be formed.

Lloyd Thomas, Plankinton, secretary of the Central South Dakota Weather Improvement Association, was present at the meeting to explain the organization of the project.

He said he started writing letters to the Water Resources Development Corp. in December to find out about the possibility of increasing rainfall by seeding clouds with silver iodide particles.

Thomas checked with persons in the project areas under contract with the corporation and found no one dissatisfied with the program, he told the farmers in Artesian.

He outlined the organization of the Central South Dakota Weather Improvement Association with the statement, "You have to convince yourself first. Then you can hold meetings and get information on the project. Then you form a temporary board whose only duty is to decide whether you should take the first step and have a meteorological survey made."

Purpose of the meteorological survey, which will be made for the central South Dakota group by the American Institute of Aerological Research, a nonprofit branch of the Water Resources Development Corp., will be to find out just what average rainfall is, the number of storm opportunities, how the economy of the area operates and the soil structure and topography of the area.

On the basis of that survey, Thomas said, the Central South Dakota Association will decide whether to hire the "rainmakers."

Ken Raetz, regional director of the corporation, told the audience that last year 100 million acres of land were under contract with the company for seeding operations.

The owner of 10,000 acres of land in Washington on which he averaged only 9 to 10 bushels an acre contracted for the seeding and got a yield of 20 bushels an acre, said Raetz.

He pointed out that the value of the seeding operations over a long period would be to increase the total amount of moisture in subsoil.

"Corn has weathered 6 to 8 weeks of no rain because enough subsoil moisfure was present," he said.

He pointed out that seeding can cut down the possibility of hail and can spread out thunderstorms over larger areas as well as increase the moisture falling as rain up to 100 percent.

[From the Gann Valley Chief, Gann Valley, S. Dak., March 15, 1951]

PLAN SURVEY OF RAIN-MAKING PROSPECTS IN 4-COUNTY AREA

Rain making has been the topic of conversation around these parts for the past week or so. I took it upon myself to look into the work that is being done in other sections of the country and the letters I got back from the people actually experiencing the benefits of increased rain, made me sure it was at least worth more investigation.

I got in touch with the Water Resources Development Corp. at Pasadena (you can read about their work in the March issues of Farm Journal and the Country Gentlemen) and they arranged to have their Midwest regional director, Kenneth C. Raetz, come out and explain the program. We've been meeting around the county and, from all that folks say, I would gather that the sentiment favors hiring the WRDC to increase rainfall for this area.

There is a lot of technical data that Mr. Raetz explained at the meetings as to why and how they can actually guarantee an increase in rainfall, but the way most

of the folks felt was that to heck with why and how—if they can increase rain at a time when we need it, let's go.

Before the company will go ahead with a rain-increase project, they insist on making a survey which will tell them (and us) just how much the rain can be increased and when, and when is the best time to operate so that it will produce the most good for the majority. If the survey shows that they can do a successful job for us, the project will cost about 3 cents per acre for each month of operation. On a project of about the size of Aurora county, the total cost for a season's operation would be in the neighborhood of $50,000, or about 10 cents an acre for the season. If we should decide to include more acreage by adding Brule and Jerauld Counties (meetings are being held in Kimball, Chamberlain, and Wessington Springs the week of February 26), the cost per acre would drop to about 6 or 7 cents per acre for the season. I don't think that anyone will quarrel about the cost, because if we only got an extra bushel yield of wheat or corn, we would show a fat profit. As a lot of the fellows have told me, "I'll gamble a hundred dollars any day, if I can see a chance of making a couple of thousand." * * *

In our minds, this is the greatest chance we've ever had to do something about the weather, instead of just talking about it. Make no mistake—the WRDC people are making it rain, and in areas where there hasn't been a decent sprinkle in 5 years.

It's time for us to stand up and be counted. The pledge below is for you. I'm down for $100 myself. Mail or bring them into the elevator. This program can go over the top. It all depends on you.

Sincerely,

LLOYD E. THOMAS, *Temporary Chairman.*

PLEDGE

It is understood that if the required amount to conduct a survey is not raised, my pledge will be null and void.

Also, it is understood that the sum below pledged will be applied against the acreage assessment for the actual rain-increase project.

Name_____
Acreage_____
Amount_____
Address_____

No pledge over $100. One-thousand acres and over, $100. Five-hundred to one-thousand acres, $50. Less than 500 acres, $25.

Senator ANDERSON. Very well, the hearing is adjourned.

(Whereupon, at 12:35 p. m., the subcommittees adjourned.)

SUBCOMMITTEES WITNESS DEMONSTRATIONS AT GENERAL ELECTRIC RESEARCH LABORATORY, SCHENECTADY, N. Y., MARCH 29, 1951

Dr. C. G. Suits, director of the General Electric Research Laboratory at Schenectady, N. Y., invited members of the three subcommittees to visit the laboratory for the purpose of witnessing the experiments being conducted by Dr. Irving Langmuir, Dr. Vincent J. Scheaffer, and Dr. Bernard Vonnegut. The inspection visit was made by a party consisting of the following persons: Senator Clinton P. Anderson, chairman of the subcommittees of the Interior and Insular Affairs Committee and the Agriculture and Forestry Committee; Senator James P. Kem, a member of the Agriculture and Forestry subcommittee; Mr. Arthur Juhnke, administrative assistant to Senator Case; Mr. Charles F. Gardner, Jr., secretary to Senator Case; Mr. Robert McKinney, Chairman of the New Mexico Economic Development Commission; Mr. Arthur A. Sandusky, staff counsel, the Committee on Interior and Insular Affairs; and Mills Astin, chief clerk of the Interior and Insular Affairs Committee. The party was escorted to Schenectady by Mr. Ward B. Stringham, commercial vice president of the General Electric Supply Co.

WEATHER CONTROL AND AUGMENTED POTABLE WATER SUPPLY

THURSDAY APRIL 5, 1951

UNITED STATES SENATE,
SUBCOMMITTEES OF THE COMMITTEES ON
INTERIOR AND INSULAR AFFAIRS,
INTERSTATE AND FOREIGN COMMERCE,
AGRICULTURE AND FORESTRY,
Washington, D. C.

The subcommittees met, pursuant to call, at 10:25 a. m., in room 224 Senate Office Building, Senator Clinton P. Anderson, presiding.

Present: Senators Clinton P. Anderson, Lester C. Hunt, Guy Cordon, and Francis Case.

Also present: Mills Astin, chief clerk to the Committee on Interior and Insular Affairs.

Senator ANDERSON. The subcommittees will be in order.

The subcommittees adjourned their session previously in order to have an opportunity at a subsequent date to hear Dr. Irving P. Krick with reference to these three bills. Our discussions at an earlier period were largely with Mr. Gillenwaters, who is associated with Dr. Krick.

Mr. Gillenwaters, I am going to ask you to present Dr. Krick to the committee, with any statement you care to make at this time.

Mr. GILLENWATERS. Thank you, Senator. First I want to express the appreciation of not only myself but Dr. Krick and our organization for continuing the hearing. It was impossible for Dr. Krick to attend the other day.

Dr. Krick is director of the American Institute of Aerological Research, which is a nonprofit research foundation, president of the Water Resources Development Corp. which has been the contracting organization for carrying on these activities, acts in the individual capacity as meteorological consultant and directs all of our activities not only in the rain-increasing programs but in the long-range forecasting, short-range forecasting, and the adaptations of weather service to the various commercial enterprises, public utilities, and items of that nature.

Dr. Krick has a prepared statement, and at this time I would like to present to you Dr. Krick.

Senator ANDERSON. Go right ahead, Doctor. I want you to present your material as you want it presented. As I understand it, you want to read first your prepared statement, then show the slides, and then open the matter up for questions and answers.

Mr. KRICK. Yes, sir; I anticipated conducting my part of the hearing in that way, if I may, so at this time I will simply read my prepared statement.

Senator ANDERSON. Will you proceed.

STATEMENT OF IRVING P. KRICK, DIRECTOR OF THE AMERICAN INSTITUTE OF AEROLOGICAL RESEARCH AND PRESIDENT OF THE WATER RESOURCES DEVELOPMENT CORP., DENVER, COLO., ACCOMPANIED BY T. R. GILLENWATERS, SPECIAL COUNSEL

Mr. KRICK. I have been a professional meteorologist for the past 18 years. I received my training in this profession as a graduate student at the California Institute of Technology, receiving an M. S. degree in 1933 and a Ph. D. in 1934. This work was followed by a tour of meteorological institutions in Europe during 1934 on a Rockefeller Foundation grant. During the period of 1933 to 1948, I was head of the Meteorology Department at the California Institute of Technology at Pasadena, Calif., and at the same time served as a consulting meteorologist to business enterprises by issuing weather advisories dealing with the effects of coming weather conditions on the concerns' operations. During the period of 1942 to 1946, I was in the armed services, serving in the capacity of scientific adviser and meteorologist, directing meteorological research programs and being responsible for certain key operational weather forecasts.

In 1948, together with the staff of the meteorology department at the California Institute of Technology, I left the institute to form a private weather consulting group and to organize the American Institute of Aerological Research, a nonprofit private research institution which undertakes scientific research in meteorology and other allied fields. Subsequently, I also organized the Water Resources Development Corp. which has undertaken various experiments in artificial nucleation on a contractual basis.

Our experimentation with artificial nucleation began in the winter of 1946–47 shortly after the early announcement by Dr. Irving Langmuir and the General Electric Laboratories concerning possible modification of clouds by artificial means. At that time, I was in charge of the meteorological department at the California Institute of Technology and the first experiments were carried out by graduate students of the department under my supervision. The early experiments involved the use of dry ice and discharge of the material into clouds by release from aircraft. Further experiments were carried out in the southern California and Phoenix areas during the following 2 years. These experiments were notable in their effect on our subsequent operational methods. Until the early spring of 1949, most experimentation was carried out using the dry ice aircraft method. During the course of these operations, it became increasingly apparent that technical difficulties inherent in the aircraft method, such as the coincidence of good seeding opportunities and poor flying weather, the disadvantages of localized seeding in contrast to seeding over a broad geographical area of the order of magnitude of natural storm processes and the lack of adequate control over the aircraft operations made the aircraft method of artificial nucleation a relatively poor operating technique. Accordingly, during the winter and spring of 1949 attention was directed toward the development of ground equipment which would impregnate the air stream with silver iodide crystals. Preliminary results of the ground technique during the spring of 1949 were considerably more encouraging than the previous aircraft operations. The following year was spent in the development and testing of equipment which would inject silver iodide

crystals of the proper size, shape, and number into the existing air stream, under varying meteorological conditions. This required research into mechanical development and chemical processes used for producing suitable types of fuel.

Also during this period, the American Institute of Aerological Research was afforded the opportunity of evaluating the results of certain experiments which had been undertaken by an unrelated organization in Mexico during the summer of 1949. Considerable valuable information on evaluation methods and experimental results was obtained from this study. Our experiments were resumed in early 1950 in California using the newly developed ground generating equipment and valuable data for future experiments were obtained. In March 1950 the Water Resources Development Corp. was formed to engineer large-scale operations. In June 1950, following a meteorological and economic analysis of the region, this corporation undertook several experiments in the Horse Heaven area of eastern Washington, near Prosser. The results of the tests again proved encouraging and we were afforded the opportunity of continuing the experimentation over a large area of northeast New Mexico and southeast Colorado during July, August, and September of 1950. The results of these experiments, together with those relating to more recent operations in Washington, Oregon, California, Arizona, New Mexico, and Colorado have been and are being continually checked and evaluated by objective statistical methods through the use of the official rainfall figures as published by the United States Weather Bureau. In addition, we have attempted to evaluate the results of other similar operations which have been reported throughout the United States.

During the past year, we have attempted to improve our equipment and operating techniques in order to achieve the most beneficial effects on rainfall patterns as a result of preoperational analysis of requirements in the operating areas.

For the benefit of the committee, I would now like to outline in some detail the various phases involved in the proper conduct of a cloud-seeding program at the present time.

It has been our policy to conduct a preliminary survey of the designated area prior to the conduct of any operations. Such analyses discuss and evaluate the meteorological and local terrain features peculiar to the area, the potential effects of increased rainfall at various times of the year within the area, and discuss any possible damages which might result from increased rainfall within the area during any particular season of the year. The decision for conducting the operations in the area and the suggested months for operation are direct results of the conclusions reached in this preliminary analysis.

Following a decision in favor of conducting cloud-seeding operations a technical preoperational analysis is prepared for the area for the benefit of the field supervisor and others connected directly with the operations themselves. This technical analysis includes a study of past weather patterns influencing the area, the effects of terrain on these weather patterns and the formulation of the operating method for that particular area and adjacent downwind areas. As a result of this study, the field supervisor is able to locate his headquarters at a centrally convenient point and to locate generator sites, one or more of which will be operated depending upon the storm pattern prevailing during each operation. In addition, the preoperational analysis

designates the weather reporting network to be used in analyzing results and establishes methods of evaluation which will assist in improving operations but will also give the ultimate results of the program at the conclusion of scheduled operations.

Following completion of the technical preoperational analyses, the planning phase is completed by the selection and assignment of personnel to the area, the preparation of the field operator's manual, preparation and dispatching of the equipment to the area, preparation and establishment of fuel supply procedures, and the establishment of a communications network between the central office and the field crews.

Field operations are conducted under the supervision of a meteorological engineer whose duties involve maintaining contacts with the local sponsoring group in addition to the supervision, maintenance, repair, and operation of the generation equipment.

All operations are centrally controlled through our principal meteorological laboratory. In this laboratory complete up-to-the-minute weather data are available for all areas of the country and an operational supervisor in the laboratory supplies the current and forecast weather information to the operational area, varying each operation according to the peculiar features of the prevailing storm in order to achieve the optimum success in the desired area. Information from the supervisor is then relayed to the local field supervisor who adjusts the conduct of the operation accordingly as the storm develops and progresses through the area.

Evaluation of each cloud seeding operation is accomplished by various standard statistical procedures, analyzing the rainfall and storm data after each storm and after conclusion of each program of operations in order to indicate the effects of artificial nucleation on the rainfall patterns which have occurred. Results of these evaluations are then applied to improving the conduct of future operations.

It is our belief that the successful conduct of cloud seeding operations requires an engineering approach such as has been described in the preceding paragraphs. Proper meteorological supervision involving the careful analysis of all weather factors occurring during the operational period in relation to artificial nucleation techniques is essential to the success of these operations.

Possible damages or hazards involved in cloud seeding at various times during the year in a particular area and adjacent downwind areas, are studied in the preliminary survey analysis. Should any damaging features become apparent, such as additional rainfall during fruit-blooming or harvest periods, cloud seeding operations may be discontinued during the critical interval. A careful study of the area prior to operations greatly minimizes the possibility of damaging effects on any interests within the area. Coordination by diverse interests through representation on the board of the sponsoring agency also tends to minimize such effects.

An important effect noted in our cloud-seeding operations has been a spreading and smoothing effect upon rainfall patterns, resulting in a more uniform distribution of rainfall over a wide area, accompanied by a minimum of soil erosion. Suppression of hail and heavy-intensity rains within the seeded area appear to follow as a direct result of this spreading and smoothing effect. This effect is attributed to the impregnation of a large segment of the air stream with silver

iodide crystals in contrast to the localized effects caused by seeding individual clouds.

Tests conducted by the Water Resources Development Corp. during the past year differ in a number of major respects from previous experiments reported in the scientific literature to date:

(1) The geographical magnitude of the operations has been considerably larger. Total area of operations has been over 150 million acres, the largest single project covering over 30,000 square miles.

(2) Sustained operations have been conducted at every favorable opportunity (each suitable storm period) over an interval of several months.

(3) The operations have been engineered to the extent that the artificial nucleation effects have been targeted over a localized area regardless of the existing weather pattern.

(4) Meteorological control and supervision of the operations has been considerably more rigid and extensive than previously attempted and more attention has been directed to the relation of artificial nucleation to natural weather processes.

Statistical treatment of the data available for analysis has been conducted along the lines of an attempt to segregate probable rainfall increases in specific areas due to the cloud-seeding operations from the rainfall amounts that might have been expected to result from natural causes alone. Through multiple correlation techniques, rainfall amounts in adjacent unaffected areas have been related for past years with the rainfall occurring simultaneously in the area of operation. Having established the interdependence of rainfall between the two areas for past years, an estimate can be obtained of the probable effects of the operations on rainfall amounts during the seeding period.

Results of these statistical tests are strongly suggestive of important modifications in local precipitation patterns. Detailed results of a number of operations conducted by the Water Resources Development Corp. will be given in a paper to be presented at the Washington meeting of the American Geophysical Union on April 30, 1951. I shall be pleased to submit a copy of this paper to the committee as soon as its preparation is completed. (See appendix.)

During the course of our operations, we have analyzed weather patterns throughout the country searching for possible effects of the cloud-seeding operations on areas far removed from the operation itself. At no time has it been possible to discern an effect of any kind in the weather conditions occurring well outside of the operational area (at distances in excess of a few hundred miles). It is our firm belief based on a background of many years of meteorological experience that no floods or droughts have been caused in any portion of the country as a result of any cloud-seeding operations known to us.

I believe that the establishment of a Weather Control Commission as proposed in S. 222 is premature at this time.

I would favor legislation which provided the following:

1. Establishment of a coordinating agency which would receive and disseminate reports of cloud-seeding activities throughout the country. According to the bill which established it, the National Science Board would seem to be ideally empowered to provide the mechanism for performing this important function.

2. In the case of private investigations, granting of licenses for cloud seeding on an application and fee-payment basis with the further

stipulation that data on personnel, experience, areas under operation, sponsoring agency, methods of operation and full reports on results obtained, operational details; such as times, locations, and materials used be filed with the coordinating agency.

I believe that such a legislative program at this time would provide the maximum possible stimulus for the further developmental research necessary in this field.

Mr. GILLENWATERS. We have some slides now, Senator.

Senator ANDERSON. Yes; go right ahead.

Mr. KRICK. Before starting with this series of slides, which I hope will help clarify some of the points brought out in my statement, I should like to review again the concept which we feel is essential to the success of operations of this type.

I believe this goes back to an understanding of natural processes in the atmosphere which produce precipitation, because our knowledge to date does not permit us to bring the state of the atmosphere to a point where precipitation may occur from these processes.

The best we can do is to wait for nature to provide these opportunities and then to try to assist nature in increasing and giving a more uniform distribution to the resultant precipitation.

Studies of the general circulation of the atmosphere which are familiar to most meteorologists indicate that the storms which occur in the middle latitudes are usually, if they are of any magnitude, a result of the conflict which goes on continually between the cold-air streams of polar origin and the moist, warm-air stream of the Tropics. There is a belt in the middle latitudes where those two great air streams, usually covering hundreds of thousands and even millions of square miles, come into conflict.

The cold polar air streams are usually so much heavier than the warm, moist air streams that they tend to underrun the warm currents and this process causes a wide-scale lifting of the warm air currents, with the resultant effect that large-scale cloud formations are produced which may yield the natural rainfall.

The lifting process results in the cooling of the warm air masses very much as escaping air from a tire when it reaches the outside atmosphere at lower pressure expands and cools. This cooling process results in the condensation of moisture which is being carried along in the warm air stream, and if conditions are right, precipitation can result from these cloud layers.

Now, in most storm situations the southwesterly current of warm air which precedes the arrival of the cold air mass at any given location is the one which provides the opportunity for seeding, and in that air stream we have cloud masses occurring in advance and during the storm which cover many thousands of square miles.

It is our view that, in order to get any economic results from this process, one must simulate nature's processes insofar as possible by supplying these nucleating materials over areas of the same order of magnitude as those occupied by these cloud systems associated with the natural storms. That is why it is necessary to maintain 24 hours a day, 7 days a week, a complete weather-reporting service.

It so happens that the United States Weather Bureau will license private consulting meteorologists to receive this information over the CAA teletype circuits. That permits one to keep in step with the changing situations in the atmosphere on a grand scale and to

key the operations to the arrival of these great storm patterns over the areas designated for operation.

That is why we must go back through past records and study the frequency of occurrence of storms which would be favorable to seeding before we can determine whether or not the economic advantages of such an operation will pay off.

There are many areas where certain seasons of the year storms of this type are virtually absent. Therefore, there would be no point in attempting an operation at that time of year.

I think with that preface I should like now to try to show you how we go about these operations and some of the results that we think have been attained to date.

Now, the first slide illustrates the type of early experiment from aircraft. This is a plane flying over a cloud in which the water droplets are at temperatures below freezing and provide the opportunity for this type of work. I am sure that previous witnesses have explained the technical processes involved here, so I do not believe it is essential to go into that again.

Now, in this case, the operator in the rear of the airplane is dispensing dry ice pellets into this cloud mass from above. These are the procedures which have been used in the early experiments in this work.

The next slide illustrates the condition below this same cloud mass prior to this dispensation of dry ice into the cloud mass.

The next slide illustrates the condition 15 or 20 minutes after the dry ice was dropped into the cloud. This is a phenomenon which has been observed many times from this process.

However, you can see in looking at the picture how extremely local this effect is. The rain or snow falls only from the cloud which has been seeded and is therefore not too important from an economic standpoint if you are attempting to eliminate or relieve a dry situation over expansive areas.

However, much was learned from these early experiments, as I have explained in my statement, and they serve their purpose. When we began to consider more deeply how this work should be done to simulate more nearly natural processes, our attention was directed to studies of turbulent diffusion in the atmosphere and the manner in which a smoke plume from a source where the materials might be emitted would develop in existing and variable meteorological conditions, and the next slide shows a typical analysis of the way in which smoke will diffuse downwind from a silver iodide generator emitting these vapors.

The upper part of the diagram is simply a horizontal projection or map view of the diffusion of these materials downwind from a source on the left of the diagram. It adds up to a decrease in concentration of the materials at increasing distances from the source and at a distance of about 170 miles from the source we have a smoke plume that is virtually 100 miles wide.

In the lower part of the diagram we have a vertical slice through the atmosphere which shows on this particular day that the smoke would have attained an altitude of around 5 miles, which is well into most cloud systems, at distances of 10 or 15 miles from the source, and the materials again are shown to diffuse at increasing

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distances from the source, so that the concentrations gradually fall off to very small values.

Now, this is on a day when temperature conditions are more or less the average in the atmosphere and the wind velocity is about 20 miles an hour.

Obviously, under varying meteorological conditions and varying vertical motions in the atmosphere, the shape of this plume and the distribution of the material will vary somewhat, but those things can be estimated within the limits of requirement so that it is possible then to station these generators with respect to a target area so that for any particular storm type that has been analyzed in the past, it will be possible to target the area with the proper number of silver iodide crystals at the levels where they will become effective.

The next slide shows diagrammatically how this operation of ground seeding, as we call it, would work. The generator in this picture is located to the left of the diagram. The materials are seen to spread downwind.

In this case the wind is blowing from the left to the right in the diagram, both at the surface and in the upper levels. These materials diffuse as they spread downwind and the vertical motions which are always present during storm conditions carry them aloft into the clouds.

Even if precipitation is active, these particles will ascend with the existing air currents because they are so tiny that they have virtually no weight and they are not washed out of the air stream by active precipitation.

When the materials attain levels in the atmosphere where temperatures are below freezing, they begin to operate upon the water vapor in the cloud, attracting the water vapor to themselves at the expense of the supercooled droplets in the cloud.

By having the right number of crystals available, these snowflakes that are thus formed will grow at the expense of the water droplets, and if they reach a sufficient size to fall out of the cloud, they do so, reaching the ground in the form of snow if surface temperatures are below freezing, but melting and arriving as rain if the surface temperature is above freezing.

Now, the essential point here when we consider the possibility of targeting a specific area, is to understand what a dynamic thing the atmosphere is. The wind movements at levels where this effect takes place may be 50 to 100 miles an hour.

That is why it is essential to have continuity of operation from a fixed location or from locations which can be keyed into the target area so that the materials arrive at the same location over the target at all times during the operation and are used up over that area in accomplishing their objective.

Now, many times a storm may last anywhere from 10 to 24 hours, so that these materials have to be released continually and at uniform concentrations during that period in order to target throughout the period a specified area.

Therefore, the operation becomes essentially a rather complex artillery operation in which the generators are the field batteries, the tiny silver iodide crystals are the projectiles which are really at the mercy of the winds, so the computations of ballistic winds and densities are the function of the meteorological organization which has

current data on wind speeds and directions at all levels in the atmosphere, distribution of temperature and humidity throughout the atmosphere, so that the computations will yield the trajectories of these particles and permit the meteorological organization controlling the operation to calculate the rate at which the diffusion will take place from the generator up to the points in the atmosphere where the action takes place.

Now, this diagrammatic representation was more or less a hypothesis prior to tests which were made in the Phoenix area in the spring of 1949.

We wanted to test under rigid controls the validity of this hypothesis, and the next slide shows a series of such tests which led us to believe that we were on the right track.

This is a series of tests with storms in 1949, in February and March, were seeded in the vicinity of the Roosevelt Reservoir near Phoenix, Ariz. We had established here a fixed location for the ground equipment.

We used only one to make this test, and we established downwind a line of rain gages extending roughly from northwest to southeast. It was our view that if there was anything to the use of ground equipment, we could discern it through this controlled experimentation.

We found that the storm winds in this area during the spring either blew at levels above freezing from the southwest or from the northwest. That is the thing that controlled the arrangement, guided us in making such an arrangement of our generator with respect to the rain gages. Now, the blue on the chart is simply the smoke plume from the generator in the case of each of the wind directions indicated. It was found that in every case the rain gages within the cone of effectiveness from the generator displayed an accumulation of rainfall three to four times greater during a given storm interval than the rain gages outside of this cone of effectiveness.

Now, the rain gages outside of this cone measured a combination of any natural rainfall that was occurring plus any rain which was being produced by the aircraft operation going on sometimes simultaneously.

The rain gages within the cone of effectiveness gave a measure of all three: natural rainfall plus anything the aircraft was doing plus anything the ground generator was doing, but the differential gave essentially only the effectiveness of the ground generator, so therefore if we found that we were consistently getting ratios of 3 or 4 to 1 inside the cone of effectiveness in contrast to the rainfall occurring outside the cone of effectiveness, we felt reasonably certain that we were on the right track.

We therefore continued for an entire year with the development and experimentation of ground equipment only in order to perfect the operation of these devices.

The next slide shows a typical experiment of this type from our laboratories in Pasadena, Calif. This was a storm in April 1950, in which the storm winds were blowing from the southwest. The generator was operated from our laboratories in Pasadena.

The materials carried downwind, diffusing as they went, and we discerned a maximum in the rainfall pattern some distance from the generators, as we had in the case of the Phoenix experiments.

In order to get a representative value for the differential between natural and induced rainfall, it is necessary to relate them to some

base, and that base in this case is the normal rainfall for the month of April in the area. So the figures shown on the chart are actually ratios of the actual rainfall of this storm to the normal for the month of April.

Now, to illustrate what I mean here, we see a figure of 0.48, which is roughly one-half at Pasadena, which is our laboratory location. Now, if the normal rainfall for the month of April at Pasadena is 1 inch, that means that for this particular storm there were forty-eight one-hundredths inch.

Now, downwind in the mountains the normals are much higher. Let us say the normal is 3 inches, or three times as great as at Pasadena.

The ratio there is 1.5 in the maximum in the pattern, so that means that there would have been 4½ inches of rain in contrast to the half-inch at Pasadana, but that does not mean that the rainfall was nine times as great that was induced by the generator operation, because when we take out this variation in the normal, it means it was only about three times as great in the mountain areas.

But those ratios again are of the same order of magnitude that we discerned in the Phoenix operation, so a series of experiments of this type during the winter of 1950 gave us sufficient encouragement that we then formed the Water Resources Development Corp. for the purpose of engineering large-scale projects in areas where the interests in the area desired to sponsor experiments of this type.

Now, the next slide is an illustration of the type of actual silver iodide generator which is used in the field for disseminating the silver iodide particles to the atmosphere. In designing and constructing this generator there were several features that had to be considered.

We found in laboratory tests that the temperatures at which the silver iodide powder could be vaporized to form the right size and shape and number of crystals was around 2,500° to 3,000° F., so in this generator we have to develop temperatures of this order of magnitude.

We found also that very small amounts of silver iodide are needed to produce these results. Practically all of these statements I am making were first issued by the General Electric laboratories. There is nothing new in the basic principles that we have worked with here. It is only in the engineering and design of the equipment that we require for our type of operation.

In order to get the necessary concentrations in the silver iodide and burn it slowly enough, we have experimented with various types of foundry coke, a porous substance, and we found that by impregnating this coke with solutions of silver iodide and acetone at various strengths, we could get varying rates of emission for crystals of the right size and shape.

Another aspect that had to be considered was the necessity for developing a generator which nontechnical personnel could operate in the field, because many times the fixed installations that are set up prior to a project are operated by farmers and ranchers connected with the sponsoring agency on the project.

At this point I will mention that none of these generators is ever sold to individuals, because of the complexity in the knowledge required to operate them. They are merely placed with individuals and their operations are strictly controlled by the field supervisors on the projects.

Now, in order to get this nontechnical aspect into the generator, it had to be virtually fully automatic and self-sustaining during a storm operation.

Senator ANDERSON. Doctor, will you stop for just a second? You say none of these generators are ever sold to private individuals?

Mr. KRICK. No, sir; not by our organization. I only say, "by our organization."

Senator ANDERSON. I am sorry. I did not get that.

Mr. KRICK. No, sir; I meant that we do not sell.

Senator ANDERSON. There are some competitive interests who have sold right along.

Mr. KRICK. That may be true, but not this particular type nor by our organization.

Senator CASE. Is the impregnation of coke a patented process or may anyone do that?

Mr. KRICK. It might be a patentable process We have applied for patents on these fuels, but since the dissemination and the development of the fuels and the release to the atmosphere is something that anyone can do, I do not feel that any patent on such a thing would be particularly important.

I think the actual meteorological control of these programs is the essential thing, not the techniques which are pretty generally known for producing the silver iodide crystals. However, I think there is considerable harm in permitting individuals to perform this operation without rigid control.

In other words, the point that Senator Anderson brings up is an important one: That it probably is unwise to have individuals all over the country with apparatus of this type emitting silver iodide at will.

However, our investigations of these things have shown that in most cases these people are conscientious people simply desiring to help themselves or their neighbors, and if a project under scientific control is developing in their area, they simply cease their operations and join the sponsoring agency, so I do not feel as yet that that is a particular serious problem, but it might become one.

Now, this generator is actuated by the storage battery which is shown in the lower right-hand corner. That drives the blower which oxidizes the flame and gives the temperatures required in the furnace, and it actuates the mechanical feed mechanism which supplies the fuels to the furnace.

In operation the door is closed and the vapors leave the generator from the vents at the top of the device, and then they are at the mercy of the winds, and that is where the meteorological knowledge and control becomes essential.

The next slide shows the tests that are made of each batch of fuel that is manufactured. We found that commercial varieties of silver iodide were not sufficiently pure for our purposes, so we had to establish our own chemical laboratories to prepare the fuels which are used in these generators.

Now, each batch of fuel is burned in a generator and a sample of the air coming from the generator is taken in this syringe which you see in the picture, and that is taken to a cold box in which a supercooled cloud has been developed, usually by simply blowing the breath into the box.

The droplets thus formed are approximately of the order of magnitude of those experienced in clouds in nature; so, by injecting this sample of air from the generator into the box, the silver iodide crystals immediately go to work and a miniature snowstorm is created in the box.

The box is of known volume, so when these ice crystals fall to the bottom of the box, we have a number of glass slides on the bottom of the box that can then be placed under the microscope to the left of the box and a physical count made of the number of crystals obtained from that sample of fuel and an observation of the crystal structure made. If this fuel comes up to our standards, it is then boxed up and sent to the field operators.

Now, a word or two about the way in which the operation is controlled by the meteorological laboratories at the central control point which is at present located in Denver, Colo.

The next slide simply shows a technician reading the reports which come in continuously over the teletype circuits maintained by the CAA and the United States Weather Bureau.

These reports are collated every 6 hours in the form of a weather analysis over the entire North American Continent and the adjacent oceans, and we also receive direct from the Weather Bureau in Washington charts covering the entire Northern Hemisphere, so that the basic pattern of weather over most of the globe can be followed rigorously by the technicians in the laboratory, so that when situations become proper for a seeding operation in any location where a project is in operation, the field supervisor on that project can be alerted.

The next slide simply illustrates the process of plotting these data at various intervals during the day to keep abreast of the change in conditions in the atmosphere as a whole. This is done by technicians who are familiar with the sources of data and the various reporting stations throughout the world.

The next slide shows the analysis of these data and the forecasting procedures.

This staff has before it the surface weather charts and the various upper-air charts, and also they study and analyze data which comes in at regular intervals during each day giving the wind speed and directions at all levels, the temperature and moisture variations in the atmosphere characteristic of the various air streams which are interacting to cause the storm developments which are then seeded.

Now, this principal laboratory is in direct wire communication with the field units, the technical people who control the individual projects.

The next slide illustrates the form in which the basic alerts to the field are transmitted.

These are simply the teletype machines maintained by the telephone company. One may subscribe to this service and retain these machines in the office. In that way you can get a direct wire connection at any time with your field office and brief it on the conditions which are developing in its operating area.

Now, in addition to the fixed units—they are supported by mobile units which are operated by our own technicians. They are equipped, in some cases, with two-way radio for contact to their field headquarters, and in every case with airways radio receivers so that they can keep in current touch with the hourly reports that the airports in the

area disseminate so that they can discern any change in situation which might affect their particular operation.

Now, the next slide is an illustration of the result which occurred of our first operation. That is under the auspices of the Water Resources Development Corp., the operation referred to in my statement of June 1950, in the Horse Heaven Hills area of Washington.

Here, again, we have plotted the percentage of the monthly normal resulting from an individual storm. This is a storm which occurred during the period June 6 to 8, 1950. It moved into the area from the northwest and swung eastward and on into Idaho.

The target area is designated as a small segment near Prosser, Wash. This was a project encompassing only approximately 100,000 acres.

Now, we can see from the pattern that it is impossible in the type of operation that we have engineered to target an area that small. Those who can see the chart will see that for this particular storm the area included within the 100-percent line, which means that they got the total monthly rainfall out of this one storm, encompasses many million acres.

The maximum in the storm was not exactly over our target. It was somewhat east of the target. This was because we did not have our adjustments on the storm as precise as we might have had. However, we did obtain 192 percent of the monthly normal over the target.

Now, the normal in that area for the month of June is only half an inch. This is a critical time in the development of wheat plants, so any additional rain is very important to the final outcome of the crop.

In this particular area the Government estimate on rainfall, or I should say on yield, at June 1, was about 7½ to 8 bushels per acre. Now, the final outcome from this operation was a harvest of somewhere around 20 to 27 bushels per acre.

Now, at least a portion of that we feel might have been due to this operation, because when you compare the percentages of precipitation upwind, or to the west of the target area and therefore unaffected by the operation since no generators were located in that sector, we see, at Seattle for example, 28 percent of normal out of this storm; at Portland, 4 percent.

The next slide shows a second storm which was treated in a similar way, but in this case the storm was entirely different. The surface winds were from the south-southeast, but the winds at the levels where the materials took effect were from the northeast. That explains, in our view, the shape of the rainfall pattern that was thus produced.

You can see that it is elongated along the axis parallel to the wind direction at the level where the seeding materials take effect. In this case, the generators were located at some distance south and east of the target area, in order to take advantage of the south-southeast material surface winds in carrying the materials aloft to the point where they became effective. Then, the rain pattern spread south-southwestward from that point.

In this case, we were more successful in targeting our area. We got just about the maximum in the pattern, 234 percent of the monthly normal, which again was over an inch of rain. I think that that

shape of the pattern is important. We do not discern a number of secondary maxima in the pattern.

There is simply one maximum, and then it shades off in all directions. That is an indication of the spreading effect and the uniformity of the rainfall pattern that can be produced through this type of operation which impregnates the entire air stream in which the storm is occurring.

Now, by June 12, here, cherries were coming into harvest in the Yakima Valley, so it was decided not to operate a subsequent storm, which came through on the 17th and 18th of June.

That storm was not operated, and the pattern reverted to the more normal pattern for the area where there were very high intensity rains in local sectors which result in soil erosion.

There were some damaging effects from that storm, but due to the fact that we were not operating the storm, there was probably no reason for relating this operation to those damaging effects. The possibility of damage was discerned in advance and the operation terminated.

The next slide simply adds up the total precipitation for these two storms of June 6 to 8 and June 11 to 12. You can see here the compactness of the pattern which was produced; the maximum which is close to the target area is 430 percent of the monthly normal, or something over 2 inches.

This is an event which had never occurred before in the annals of weather records for the area. That does not mean that the seeding operation was entirely responsible for it. It is merely suggestive that there is something to this idea.

Now, the next slide is a statistical analysis of this project which was conducted by the mathematics department at Cal-Tech. This again, in itself, is not conclusive of the benefits as the result of cloud-seeding operations. It is merely suggestive of what may be a positive result.

The graph to the left of the diagram illustrates the normal rainfall for the month of June, and from the scale on the right you can see that is about a half inch. The second bar is the previous all-time high for Prosser, Wash., which is the area of operation. The record is 36 years in length.

The third shaded bar for June shows the actual precipitation for that month which you can see tops by a considerable margin the previous all-time high.

Now, the mathematicians computed that the probability of this event occurring naturally was not greater than 5 in 1,000; in other words, once in 200 years.

Now, that in itself, as I say, is not particularly significant, but when the same calculation was performed for areas outside the target area unaffected by the operation, the probabilities of the actual rainfall that did occur were much lower.

Senator ANDERSON. Did you seed only in June?

Mr. KRICK. We only seeded in June during the 6th to 8th, and 11th to 12th, as illustrated.

Senator ANDERSON. Did you seed only in the month of June?

Did you seed in July, for example?

Mr. KRICK. No, sir; we did not.

Senator ANDERSON. Nor May?

Mr. KRICK. No, sir.

Senator ANDERSON. Nor April?

Mr. KRICK. No, sir.

Senator ANDERSON. Will you seed there this June, again?

Mr. KRICK. The chances are we shall. The operation was reestablished. You see the operation is in phase there with the growing seasons on winter wheat. Now, they plant the winter wheat up there in late September, so the operation was resumed and has been going on since that time in the month of October.

Now, the next set of bars is the evaluation for the October operation. Again, we have the normal which is something under an inch. We have the previous all-time high, and then we have the actual rainfall for the month of October this last year. Again, the probability is not greater than about 10 in 1,000, or once in 100 years.

Now, the next set of bars is a statistical analysis which represents the probability of these two events occurring in any single year; in other words, the June plus October analysis. Again, the combination of the two normals first, and then the all-time high, and then the actual rainfall for June plus October, which gives a probability of not greater than 1 in 20,000.

In November and December similar results have been obtained so that these probabilities now are even lower, but the complete analysis and the data are not yet available. However, it is interesting to compare this combined June-plus-October total with the yearly normal for the area.

As you can see, it is well up on that curve, which is the last bar on the chart. The yearly normal was exceeded in November and everything since November is in excess of the yearly normal in the area.

Now, as I have said before, this sort of statistic is not in any way conclusive evidence of the success of the operation, but it is suggestive of some results.

The next operation which we were afforded an opportunity on was in New Mexico, and I would like to now review that operation which was much more extensive in area and operated over a longer period of time. The area in northeastern Mexico outlined on the chart was the operating area.

This project started on the 4th of July 1950, and terminated on the 12th of September. During this operation every storm situation which, in our view from our preoperational analysis was susceptible to treatment, was operated on.

Now, the areas on the chart show the air flow during the storm intervals, first in July and then in August and September, at the levels above freezing where the materials would be taking effect.

In each case, the winds are seen to be blowing at these levels from the west, so that means then that if we are to get a comparison between the rainfall which occurred in the target area and the areas unaffected by the operation, we should use control stations within the target area, and to the west of the location of our generators which were all within the western edges and inside the target area.

Now, I have with me a complete log of the operating record, the location of the generators, the operators' names, and so on, which I will be glad to submit to the committee for study, but here I will merely review the results of the operation.

The triangular points within the target area are the official Weather Bureau reporting stations which were used to discern the amount of

rain that fell within that target area. By averaging those eight stations we get a representative rainfall figure for the target area.

Senator HUNT. May I ask you: The target area in acres or square miles?

Mr. KRICK. It is approximately 15,000 square miles.

To the west and northward and southward, the dots on the chart are the control stations which were used to discern what the precipitation was in the areas outside the target.

Now, naturally, there is an interdependence between the rainfall in all of these areas when no operation is undertaken because of the magnitude of natural storm development, so we also have to go back through our past records and discern what the normal differences are between the target area and the control area.

In other words, what is the normal ratio of precipitation in those two areas because they are in different climatic zones.

It turned out that the target area in years past during the months that were analyzed, which were the operational months, is approximately 40 percent wetter than the control area, so that had to be taken into consideration.

Senator ANDERSON. May I stop you there for just 1 second? Those show patterns of air coming from the west.

Mr. KRICK. Yes, sir.

Senator ANDERSON. Is the Gulf of Mexico the source of any of this water?

Mr. KRICK. The Gulf of Mexico is the source of a great deal of this water, and usually the upper winds shown there make a wide sweep westward and then recurve and come into the area from the west.

The surface winds usually come up more directly, and in most cases the surface winds would be southerly, and so the generators were located in such a way that the surface winds which would influence the initial diffusion of the material would carry it northward from the generator as it ascended into the clouds over the mountains, and then as the storms developed they would spread eastward through the plains area.

Senator ANDERSON. What I am interested in is: There was a newspaper article that said, in reference to that target area in New Mexico:

> The current of moist air which is tapped by the rain makers originates in the Gulf of Mexico and swings northward up through the Rio Grande Valley, and then on through central and northern New Mexico.

It seemed sort of impossible to me.

Mr. KRICK. What was the source of that article, Senator?

Senator ANDERSON. This is an article in a paper called the Portales Tribune. It is based upon statements made to the cattle growers at the time they were considering a contract, as to whether their contract had any influence upon other parts of the State, and it seemed in conflict to most of the theories of the Weather Bureau, at least as to where these patterns came from. There it seems to be coinciding exactly with your map.

Do you have any comment as to this possibility that if it came from the Gulf of Mexico and followed up the Rio Grande, that you were tapping those sources?

Mr. KRICK. Well, I think it is safe to say that the moisture in the lower levels of the atmosphere comes up through the whole northern

part of Mexico into Arizona and New Mexico. There is no particular narrow path that these air streams take.

They are very widespread in character, and in the summer months that air from the Gulf of Mexico will pass across Mexico as far west as southern California, so that there is a broad band of this air that comes northward, and then as it recurves and moves eastward you get in New Mexico the sort of trajectory that is shown in that August–September flow at the higher levels, but the surface winds are still pretty much from the south and southeast and southwest.

Senator ANDERSON. I understood you to say that at the level where the silver iodide was effective the winds were coming in the direction indicated on that pattern there.

Mr. KRICK. That is right, sir.

Senator ANDERSON. Therefore, the surface winds would not be so important.

Mr. KRICK. That is right, sir, except in the calculation of how the materials will be diffused from a point at the surface.

Now, the next chart shows the type of analysis that we processed to determine if there was any differential in the target rainfall in contrast to the rainfall in the control area.

The lower graphs on the chart show the ratio of rainfall in the target area to that in the control area, and the white bars are the ratios that occur in normal years where there is no operation going on, because they represent the compilation of all data prior to the operation in 1950, and you can see that in all months, July, August, and September, that ratio was roughly 1 to 4, which means that the target area is normally about 40-percent wetter than the control area.

Now, the shaded bars were the actual ratios which were measured in 1950, using the stations indicated on the previous chart, which show that in every case the target area was very much wetter than the control area and approximately twice as wet as in previous years in relation to the control area.

Now, the September bar is shorter than the August and July bars, but that is, in our view, due to the fact that the operation terminated on September 12 and that bar represents only about 12 days of the month.

Now, the ratios in July and August and September were never exceeded in the past between the control area and the target area, which is again suggestive that there must have been some effect of the seeding operation and it was possible to target it to a specific area.

Now, the bars at the top of the chart are actual rainfall figures. The first shaded bar in July shows for example that the average of the eight stations in the target area was over 6 inches. That was an all-time record for a number of those stations.

Now, by applying the normal ratio of target area to control area to the actual July rainfall in the control area, we can get an estimate of what the rainfall should have been in the target area had there been no operation, and that is the second stippled bar which is marked "Estimate."

Now, that shows that July would have been a pretty fair month if there had been no operation at all, because that estimate is slightly above the normal, which is the white bar. All of that means that July was an excellent month for the operation, because there was a high frequency of seeding opportunities during July. The difference

between the estimate and the actual, which would be the difference in the first two bars, is substantial.

In other words, the actual was just about double of what might have been expected had we not been operating, based on the analysis of the previous relationship of rainfall in the two areas and their interdependence.

Now, the next series for August is interesting, because the ratio of the rainfall in the control and the target area was about the same magnitude as in July, but there was a terrific variation in the actual rainfall. In other words, nature did not provide very many opportunities in August for the operation, in contrast to the opportunities that were afforded in July.

However, the estimate is still only about half of what the actual rainfall was in August, but both of them are below the normal.

Now, in September, the same analysis shows that the actual rainfall was above normal and considerably above the estimate for the month, which was just slightly below normal. Now, the combination of the July and August actual rainfall yielded good grass in the area.

The combination of the estimates there for July and August, or what would have happened if no operation had been going on, indicates—at least, that is the opinion of the ranchers in the area—that the grass would have come up in July but probably would have died off in August and would never have matured properly, whereas, with the actual rainfall that occurred, the grass matured nicely and, in fact, by the 12th of September it was felt that no further rain was needed and the project was terminated.

Now, the next slide simply shows illustrations of the condition that was prevalent in the upper atmosphere in a previous wet year, and in the year where seeding took place. This was another way to get at least a suggestion of what the operation may be worth.

The top two bars are the actual moisture content as measured by the daily radiosonde observations made by the Weather Bureau in the air mass that prevailed over the area.

We took a year which was a wet year, first, and that is the white bar. That is 1949, which was the wettest July in 23 years.

Now, the absolute moisture content in the air, which is a measure of the potential of that air stream to produce rain, was something over 8 grams per kilogram of air. In 1950, the amount of moisture was somewhat lower. You can see from the shaded bar that there is a difference of maybe 15 percent.

Now, the lower two charts, or the bars, are the actual rainfall in the target area, the average of the eight stations that were used in the analysis, and you see that in 1948 the amount is perhaps 30 or 40 percent less than in 1950. So, that seems to indicate that, with the same potential for rain production in the air stream, more was milked out of that air stream by the operation in 1950 than occurred naturally in the wet year or 1949, which had a higher amount of moisture available in the air stream.

Now, the next slide gives a more realistic evaluation, perhaps, but it is quite subjective. This is simply a picture of a water hole near Roy, N. Mex., which, in the recollection of the residents, had never been in this condition in previous history of the area. That was taken about 3 weeks after the project began, or close to the 1st of August.

The next slide is simply a picture taken out on the range, of the condition of the grassland at about that same time. This is grama grass; and, although it cannot be seen from here, it has headed up, and, apparently, according to the people in the area, was one of the finest stands that they had ever experienced.

Now, again, that does not mean that the operation produced that. It is merely suggseted by the analysis that has been made, but there will have to be many more operations of this type and many more analyses before one can get a quantitative and realistic measure of just what can be done with this thing.

Well, now it seemed valuable to us to apply the results of this New Mexico project to an adjacent area dominated by the same meteorological conditions, and an area in which there was an interest in this type of work. So, we took the experimental data from the Santa Rita Range Station in southeastern Arizona and applied the results of this project to those data to see if we could discern in a quantitative way about what the increase in cattle or stock production might be if a project of this type were sustained over a long period of time.

Senator CORDON. That is made, Doctor, on the assumption that the increased rain was induced by this operation?

Mr. KRICK. It is made on this assumption: that we would be able to increase the rain in Arizona by the same ratio that we feel the rain was increased in New Mexico during those summer months.

We felt that the rain was probably about doubled. That does not mean that we doubled the normal. That means that we doubled whatever came along. So, we call that doubling natural rainfall; but in this study, to be conservative, we used a figure of 75 percent increase. So, those two graphs show a relationship between August rainfall and annual forage yield in pounds per acre in the Santa Rita experimental range.

We found that in the perennial grasses usually the yield can be correlated almost directly with the August rainfall because it is in September that these grasses mature, and 93 percent of the forage is due to the grasses that mature at that time.

Therefore, the solid curve marked "nonseeded" is the relation between annual forage in pounds per acre on the left and the inches of natural rainfall in the month of August; and we see that up around the August normal, which is somewhere around 3 inches, the average forage yield is something like 400 pounds per acre per annum.

Now, by increasing the August rainfall by 75 percent, we get the second curve, which is marked "seeded," and again we get the maximum increase in forage yield up around the normal for the month.

In other words, if we can increase the rainfall by 75 percent and there was going to be a natural rainfall of around 3 inches, we would get the broken curve just above 3 inches, which gives an annual forage yield of around 600 pounds per acre per annum.

In other words, about a 50-percent increase in the yield of grass, and presumably that would therefore sustain approximately 40 or 50 percent more head of cattle in a given area.

The next slide shows an application of this study to some long-term records at Santa Rita from 1926 through 1933. The solid curve was the average yield as given by the statistics of the station for that period, which was around 450 pounds per acre per annum, and

if we had seeded during each of those years only during the month of August, getting the result that we think we got in New Mexico over that period of time, it would have increased the average yield by approximately 200 pounds per acre per annum, or 40 percent. So, we feel that that indicates that a long-term program in an area of this kind, which is submarginal, might help to stabilize the economy of the area and tend to give an increase annual production of stock in the area.

The next slide illustrates an entirely different type of operation. Over the High Plains area in Colorado we discerned from our preoperational analysis that there are very few storms in the winter months; therefore, very few opportunities to work. There is also very little rainfall from each storm, or snow fall.

Therefore, even if we could double the natural precipitation during winter, it would be of very little economic significance, because double nothing is still nothing.

However, back in the high mountain areas of Colorado and in the Southwest you do have a persistence of cloud cover during the winter months which may be induced to yield greater amounts of snowfall in these watersheds than nature might provide. This could be a very valuable asset to the areas in the drainage basins, which might be thus affected, because, if ample storage facilities are available, water can be stored for spring and summer irrigation.

So, it was determined and decided by the sponsoring agency in Colorado that we would attempt this winter to increase the snow pack in the upper Arkansas River Basin. The objective here was not to produce necessarily a maximum but to produce an optimum snow cover dependent upon storage capacity downstream and current water in storage, coupled with any long-range estimates we might make of the over-all winter situation.

We had estimated in October that the months of November and December particularly would be virtually without precipitation in these areas out over the plains, but that we might do some good back in the mountains; so, we decided to attempt this program. Part of the objective here was to work at elevations above 10,000 feet to attempt to provide snow cover that would be sustained during the spring months and melt off slowly and thus prevent flash floods in spring with the first thaws, and to supply for as long as possible a constant flow of water for irrigation. This program was inaugurated on November 1.

We felt that we were accomplishing something, and by December 15 a special snow course was run for the operation. Six stations were used in measuring the water content of the snow, and it was found that by December 15 the water content of the snow at these six stations averaged 7.6 inches against a normal for February 1 of 7.9 inches.

Well, we felt that again this was suggestive that the seeding operation was accomplishing something, for this reason. We had by December 15 in a drought year produced a snow cover comparable to a normal February 1, a month and a half later.

The actual calculation of the percentages of the snow or precipitation in relation to the normal in the operating area and in the plains area was even more significant than in the experiments previously evaluated. As you will see from the chart, the absolute maximum at

the center was 250 percent of normal against areas to the south which were unaffected in any way by the operation of approximately 25 percent.

Now, these are ratios of roughly 10 to 1. That simply means that over the plains, where there was practically no storminess to work on, very little rainfall or snowfall accumulated. However, up in the mountains, where the cloud systems persisted over the mountain peaks even after a storm. and frequently occurred when there was no storm out over the plains, it was possible by continuous operation to build up and accumulate a significant snow pack.

The result of this operation led other groups to become interested in this snow-pack program. A program was started in the San Luis Valley area—I should say the drainage basins which provide the water for the San Luis Valley—in late June. They receive water from the upper Rio Grande. This also became interesting to the Elephant Butte irrigation district in New Mexico, and it contracted for a program which started practically the 1st of February.

In these two cases the snow condition when the program started was somewhere around 10 to 15 percent of the seasonal normal, very low indeed. By March 1 the snow survey showed that the upper Rio Grande was approximately 65 to 70 percent of seasonal normal, and the northern drainage basins into the Rio Grande, the tributaries in northern New Mexico, had been brought up to 45 to 50 percent of the seasonal normal.

Now, we again feel that probably the operation contributed somewhat to that improved condition. We have now been operating in the entire State of New Mexico since about the 1st of March. We have had about three opportunities.

We had one good opportunity the end of March, and we are at present operating there, yesterday and today, and we feel that the results are encouraging. The entire State of New Mexico now has been pretty well wet down, and possibly a portion of that has been due to the operation.

I think it is safe to say at this time that we have every reason to believe that the drought is broken and will continue to be broken in New Mexico, because every storm which enters the area from now on will be operated, and any increase that can be attained over natural precipitation will be valuable because of the extreme condition that has been reached from a long period of dry weather.

Senator ANDERSON. May I just ask a question there?

Mr. KRICK. Yes, sir.

Senator ANDERSON. It is true that the State is all under an operation and I think, fortunately, it is all under the same operation. Do you not think there would be a danger to the success of the work you are trying to do if miscellaneous individuals were allowed to buy generators and seed whenever they desired?

Mr. KRICK. I do.

Senator ANDERSON. Thank you. That is the point I am trying to make. I think it is an extremely fortunate thing that virtually our entire State is under one management, so to speak, in this experiment, because I think you can see the possibility if I should decide, since I have been notified that I will not have any irrigation water after June 1, that I will get myself a little generator and stoke it up every time I thought an opportunity presented itself.

It might completely conflict with the work that you are trying to do upon which you have meteorological background and I have not. That is the whole point, I might say, Dr. Krick, of the attempt I have made in this legislation.

I am not in any way opposed to people signing up contracts for the seeding of clouds and attempting to increase natural precipitation; but I think, if everyone gets into the act, people who know what they are doing and people who do not know what they are doing, that we might completely change the possibility of beneficial result from the work that is underway. That is the reason I asked you that question.

Here seems to be an increase in the snow pack. You know how people feel who are down below that snow pack and who have to depend upon its melting for their irrigation water all summer. When the project says it is only 20 percent of normal, we say that is pretty dangerous for us. You think you have increased or helped to increase at least the size of that snow pack, and maybe the water density of it.

Some miscellaneous person not connected with any scientific group in any way, with no knowledge of meteorology in any way, might himself try to do a private job, and in my opinion could neutralize the very thing that you are trying to do.

Mr. KRICK. I think that that is definitely true. I think that up until now there probably has not been too much damage from that sort of thing because of the lack of knowledge that people in that category would have and the fact that the equipment that they would use would probably not even be effective.

However, that is definitely a possibility in the future because as more knowledge is acquired and people begin to view this thing as a reality, there will obviously be any number of people who, as you say, will get into the act, and so I concur with your views completely on that.

Senator ANDERSON. Just in the last couple of days—I have not had an opportunity to check it yet—I learned that when the valley in which I try to farm was in tremendous trouble with water last year, two individuals who had property elsewhere, not connected in any way with organizations that pretended to have any scientific knowledge, not connected with your organization or any organization that tried to do this on a regular basis, engaged a private airplane and took off from the Albuquerque Airport and seeded clouds as soon as they came over the Sandia Mountains with about 10 times as much dry ice as most careful operators think would be desirable, and then wondered what happened to them because the clouds disappeared.

I do not know whether the seeding with the dry ice had anything to do with the sudden disappearance of clouds because I have been disappointed several times in the performance of clouds, but they looked as though they might produce rainfall, and in both instances with this very heavy seeding, just as soon as they would drop over the mountains the clouds seemed to completely disappear.

It is that sort of thing that I think is dangerous in the extreme, particularly dangerous when we know nothing about it. If we know what it is and have it reported, you may be able to conclude that that is a dangerous pattern to follow.

Senator CASE. Mr. Chairman, if all this testimony would suggest that here is a field of natural monopoly, however, it would also argue that in a field of natural monopoly Government control would have to go to the regulation of rates that might be charged.

Senator ANDERSON. I think at the present time people who are buying services of this nature seem quite well satisfied with the services for which they are paying, and it might be, eventually, that if there was a natural monopoly you would want to look into it.

I do not think that the proposal to regulate and require the licensing of people who are in this field, with some restrictions as to what they should know, might tend to build some natural monopolies of which yours might be one. That does not frighten me in the slightest compared with the fear that I have concerning those individuals who may be operating and who may be damaging weather for the rest of the country.

I think that in this field any attempt to set up standards for a while, at least, will result perhaps in monopoly, just as in the passage of the Civil Aeronautics Act, and the granting of a few licenses for example to fly up and down the east coast, resulted in a virtual monopoly for what is now Eastern Airlines. Now there is plenty of competition in the field, yet it took that early original virtual monopoly to bring business to a satisfactory standard.

Mr. KRICK. I hope I made it clear in my statement that we are not interested in a monopoly. In fact, we feel that competition is a healthy thing and our real concern here is to see that there are no restrictions upon qualified groups to carry on research, but that that research be coordinated by some objective independent agency which has no connection with the subject at all, so to speak.

Senator ANDERSON. Well, that is not far from the objective that I had in introducing the bill.

Senator HUNT. Doctor, I want to ask you what is the altitude of the mountains in Colorado over which you operate.

Mr. KRICK. The altitude ranges up to something over 14,000 feet. We try to so control our work that the snow cover that we feel we may have something to do with occurs largely above 10,000 feet, so that it would not in any way interfere with wildlife, recreational activities, or come down with the first spring thaw, the objective being to provide sufficient snow cover to fulfill the requirements of the area downstream and to prolong the stream flow as long as possible into the summer months.

Senator HUNT. That was what I had in mind. We like, of course, in the mountainous areas an early pack of snow because it freezes very hard and then, as the late summer months come on, it retains the water supply for us. Apparently you have already covered that phase in your investigations.

Mr. KRICK. Well we try in our preoperational analysis through our hydrometeorological division to discern these problems and operate in such a way that the optimum benefits will be attained from the program.

Here is another type of program in which the objective is to increase stream flow for the generation of hydroelectric power. This is a project in the Pacific Northwest. This is a program in which we are retained by the organization at a base fee and we earn additional bonus payments on the basis of performance.

The objective here is to try to augment the stream flow in the early months in order to build up ahead for the operation of the generating system through increased storage. The engineers of the company have computed a point on the stream-flow curves where

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that bonus should begin and end. There is a data medium which is about midway between the minimum and maximum bonus.

Now the chart shows the stream flow along the left-hand side in second-feet per day, and the three bars give the picture for October, November, and December. The lower group of points is the flow at which we begin to get a payment. The middle point in each case is the data medium from the long-term records.

The upper point is the point at which we reach our maximum bonus; I should say the third point on the chart.

The upper points which are joined by the broken lines give the actual flow during 1950 which exceeds the flow required for payment of the maximum bonus, but apparently has been desired by the company to determine whether or not over a long period of years it would be proper to increase the plant facilities on that stream should a sustained flow of this magnitude be possible from the operation.

Now the next slide, which I think is the last one, illustrates a point which very frequently arises in the discussion of this work. One of the most common questions put to us is: Does this operation rob anyone else of his rightful rainfall.

Now the answer to that question, for several reasons, is "no" because, in the case of natural storms, their energy is sustained by a constant supply of fresh moisture, so that in the case of a storm moving, say, from California eastward to the Mississippi River, if nothing at all is done to that storm it continues to rain as the storm moves eastward and the new sources of moist air are brought into the storm.

The rain in California does not remove the moisture from that air stream. In fact, as it gets east of the Rocky Mountains the very moist currents of air from the Gulf of Mexico will very frequently increase the intensity of the rainfall pattern and the extent of that pattern.

There are other reasons why this operation probably has no effect upon others if it is conducted properly. The materials used to start the precipitation process artificially seem to operate at higher temperatures than the particles in nature which normally perform this function, so there is usually a segment of the cloud which is the segment from which most of the increase in precipitation may occur which would be untouched by natural nuclei.

And the final point, which is probably the most important one, is the fact that at any point, as a storm passes through, there is probably not more than one-half of 1 percent of the total amount of water in the air mass flowing overhead that is precipitated as rain or snow.

Therefore, even if you double the natural rainfall, you are not getting over about 1 percent out of the air stream that is moving by, and usually the replacement of that moisture by the continued supply of warm air in the storm, plus turbulent mixing processes in the atmosphere, will replenish that loss of moisture. So I think it is safe to say there is no real need for concern over the possibility, if a proper operation is performed, of damaging anyone by removing water which is rightfully theirs.

Now I use this chart as a possible means of illustrating the point. This chart shows the path of the storm center from January 10 to 13. It entered the Pacific coast area on the 10th of January and moved on eastward in the path shown during the next 3 months.

There were operations going on in California, in southeastern Arizona, and southeastern Colorado at that time, of which we know. Some of them were ours; some of them were those of other operators whom we regard as qualified.

In the case of California there are two centers shown there in which the number 50 is shown. That means that out of that one storm 50 percent of the monthly normal for January occurred.

Then in the area that was not under operation, to our knowledge, as the storm moved on eastward through Arizona, the amounts of rain were down around 25 percent of normal for that storm, which is about right because if you get three or four storms of that magnitude during the month, they produce your normal.

Down in the southeastern sector of Arizona you see a figure of 100, which means in that area 100 percent of the monthly normal occurred for that particular storm. That again was one of our operating areas.

The generators in that case were operated mostly in Mexico, so you see this problem really has some international implications, as well as the other implications that have been mentioned here.

We have arrangements which permit us free access to that country, and it is possible to operate in Mexico to target the areas in southeastern Arizona and southwestern New Mexico, because in these storms, as the storm which is passing through now which we are operating in very much the same way, the flow of moist air comes up from the southwest, and many times we must operate 100 to 150 miles from our target areas in order to do this job and get the materials diffused through a sufficiently great portion of the air stream.

Now that does not mean that the areas in which we are releasing these materials are being overseeded and any precipitation decreased, because at the surface there will be no cloud.

In cases where we operate that distance from the target, it must mean that the cloud masses at the levels where the temperatures are below freezing must be 10 to 15 thousand feet above the surface, and it takes that distance downwind for the materials to rise to those levels where they take effect.

They have no influence whatsoever on unsaturated air.

Senator CASE. Dr. Krick, in newspaper accounts of meetings that a number of farmers have been having with your Mr. Raetz in South Dakota, in response to this question he is quoted as having said that the silver iodide that you were using would be dissipated in the course of about an hour so that continually it would not have any effect days afterward or very many miles beyond.

Mr. KRICK. Well, I do not think that was a very good answer. He is not a technical man and I will have to check that because that is not a particularly good answer.

There is some discussion going on in scientific circles about the possibility of silver iodide losing its effectiveness in an hour or so if exposed to direct sunlight. Well now, normally, since we do not operate unless there is a storm prevailing, the materials will not be exposed to direct sunlight and they are free to carry on their work until such time as they are used up in the clouds where the temperatures are below freezing.

Now in some cases even 100 miles from a target it would be possible for the materials to move that distance in an hour or two, but that is

extraordinary. But of course it is in those cases that we would have to operate that distance from the target.

Now in the summer situations in New Mexico, the data I have here show the location of the generators with respect to the target, as you will see, show that they are all within the target area.

Well that is because in the summer during the period that the materials are getting up into these levels where they are then carried swiftly downwind, there are relatively light air movements, so it does not take the materials very long to get up into the areas where they will do their job in relation to the movement of the air stream between the surface and those levels.

Senator CORDON. Doctor, one of your slides, as I recall it, indicated that the silver iodide missiles reached their operational level in about 15 miles. That was the slide that indicated the form of the smoke plume.

Mr. KRICK. That was in a particular set of conditions where the wind was only blowing at 20 miles per hour and you had a fairly good vertical component in the atmosphere. As I believe I stated, that represents just one set of conditions.

Now every storm situation is different. There are no two absolutely identical storms. There are, however, some similarities between storm patterns which can be discerned and you can offer it in more or less a similar fashion for those type storms within the requirement of this particular type of operation.

Now, in general, I think we can say that when the freezing level is low and the winds are light, you can operate practically within your target area. When the winds are strong and the freezing levels are high, you will operate at great distances perhaps from your target area.

Senator CORDON. That means, then, if we may assume that the results which we have seen here illustrated in the diagram flow directly from seeding operations, that safety in the matter of adequate diffusion of the particles so as to obviate too heavy a charge which might overseed rests upon complete meteorological data and particularly the rate of speed of the wind; is that right?

Mr. KRICK. That is correct, plus the level of freezing temperatures and the moisture content within the cloud masses that are to be seeded.

Senator CORDON. Mr. Chairman, would this be a proper time to ask the doctor for his views with reference to overseeding so far as the results indicate that there may be such a thing both with respect to dry ice and to this other agent.

Senator ANDERSON. This is the appropriate time for any questions the Senator from Oregon may desire to ask.

Senator CORDON. I am very much interested in that.

Senator ANDERSON. I had some questions that concern me too as to the possibility of overseeding, for example in the immediate area around the generator.

Senator CORDON. I prefer that you go forward with them because you have knowledge of them.

Senator ANDERSON. What about the possibilities of over-seeding from an airplane in the use of dry ice? Does that disappear when the use of silver iodide comes into the picture? Does it eliminate the possibility of overseeding? Is there a possibility of overseeding right in the immediate target area?

Would you deal with that question a little bit, because there was a theory expressed here that it might be possible to so overseed clouds on the western slope of the Pacific that might result in clouds not precipitating their moisture there but moisture may be carried inland by windstorms and deposited on the eastern slope of the Rockies, thereby benefiting the areas in Senator Cordon's home State and Washington that are now drought areas, while the seacoast is receiving more water than it needs sometimes.

Mr. KRICK. Well, I think that a hypothesis of that type is probably worth considering. However, I shall try to deal with——

Senator ANDERSON. Deal with the dry ice first.

Mr. KRICK. I shall deal with the observed facts as far as operation and those of others that we have evaluated are concerned.

I think, first, to answer the question of whether or not you can overseed a cloud, in my view the answer to that is yes, that you can. I think you can overseed a cloud either with dry ice or with silver iodide.

I think that it is easiest to overseed with an aircraft because usually to get any effects at all with silver iodide seeding from an aircraft it is necessary to put out much more of the material from the point of emission than would be required to perform the seeding operation, in order that that material diffuse over an area of any size at all. That is also true of a ground generator.

However, the differences in the operating techniques are such that normally the aircraft operator flies right into the cloud that he sees that should be seeded, and knowing that these materials take effect at about the freezing levels, he flies at the freezing levels and releases this material.

That tends to overseed right at that point, and it has been observed that the clouds will dissipate and spread out due to that action, and then somewhere downwind maybe 50 or 60 miles, which can be in any direction depending upon the wind, the residual materials may encounter cloud forms that are susceptible to seeding and a positive result obtained.

Now, that type of operation I think we have observed in several instances on projects that we have evaluated in which aircraft operators, independent of our organization, were at work. We actually used the process of overseeding in our dry-ice operations in Arizona in the summer of 1948, with this hypothesis in mind.

If we could overseed the clouds on the periphery of a central thunderstorm core and induce precipitation, which in its entrainment effect in falling out of the cloud would increase a downdraft effect, the hydrodynamics of that system would tend to intensify the updraft region in the core of the thunderstorm area and induce a self-propagating storm.

We have never found it very practical to use dry-ice seeding to get the large-scale effect over wide areas that we are now engaged in operating.

Senator CORDON. Do I understand you to say that in that experiment on this periphery you overseeded with dry ice?

Mr. KRICK. Yes, sir.

Senator CORDON. If you overseeded it would not result in any precipitation, would it?

Mr. KRICK. Yes; I think it would. I think the idea of overseeding to dissipate precipitation completely is not too valid an assumption.

What the overseeding does is simply take the water out of the existing cloud pretty well and in that effect you cause rain to fall from that cloud, but then the cloud dissipates and there is no more left to it, and the thing does not propagate into a storm of any proportion. At least, that has been our observation.

Whether that, which is a very subjective thing, is real or not, we do not know, but we do know that we do not practice that any longer because there is a very limited potential to that type of work.

Now, the problem of overseeding from the ground, I think that too might be possible where your ground generators were located very close or within the freezing level of actual cloud formations.

However, where the generator, as is normally the case, is located in cloud-free air, whether it be above or below freezing, it takes a certain time then for the material to diffuse downwind and reach a cloud form upon which it will operate.

Therefore, even in areas where temperatures are below freezing but there is no cloud form on the ground, it is possible to so adjust the volume of material release so that ground seeding will not overseed the atmosphere in the intervening space between the point of emission and the point downstream where the materials begin to take effect.

Senator CORDON. Let us stay with overseeding just a moment. I understand you now to say that overseeding by dry ice you believe causes precipitation, but it also causes the cloud itself to dissipate.

Mr. KRICK. Yes, sir.

Senator CORDON. What is the effect, then, or is it the same effect, let us say, with respect to the use of silver iodide that is released in its concentrated form in a proper cloud formation at the appropriate freezing level? Does that cause precipitation?

Mr. KRICK. Yes, sir; I think that it might tend to cause precipitation. I think it would also be a little different action taking place than in the case of the dry ice. The dry-ice process, as I understand it, is simply one which cools the air on contact with the dry ice to a point where ice crystals form spontaneously. Therefore, it can never have anything but a pretty localized effect.

Now, the silver-iodide technique actually supplies the finite particles which have the same crystal structure as ice and fool the water vapor in the air, if it is at the proper temperature, into thinking these particles are ice and the moisture attaches itself to these nuclei, so therefore it is probably not correct to draw these comparisons because the mechanism is entirely different in the two cases.

The practical result, I think, is probably a little different also. In the dry-ice cases the effect is completely local where you dump the dry ice, as far as I can see from what knowledge we have of the subject. In the case of silver iodide it is different because the silver iodide is taken up by the air stream and diffused with the downflow of the air and the turbulent motions that always exist in the atmosphere.

Now, if you have too many crystals of silver iodide in this cloud, it is conceivable that it will use up all the water or a good part of it in forming such tiny ice crystals or snowflakes that they have not

got enough size to drop out, and there is no longer any water vapor left in the cloud, the whole cloud is ice then and nothing happens.

Senator CORDON. There is no precipitation then because there is not enough weight for gravity to pull.

Mr. KRICK. There is no precipitation within that particular stratum in which the silver iodide is developing, but that does not mean there will not be other portions of that cloud where natural processes are taking place, so I do not think you can completely eliminate precipitation from a storm situation by that process.

What I have observed is that it might be cut to 50 percent of what would have occurred normally, something in that order of magnitude.

Now, if you have too many silver-iodide crystals and they are not even all used up in this process of overseeding in this particular stratum, the residual material can drift on down and perhaps some place downstream the concentrations will be just at the critical value to go ahead and induce active precipitation and augment whatever is going on in the other layers of the atmosphere, you could get a maximum in that pattern then downwind and a minimum where the material was first released.

Senator CORDON. In discussing that matter you have limited yourself to the crystals unused in the first instance. What about the silver-iodide crystals which did attract all of the moisture in that area, became very tiny bits of ice, and floated on?

Would those tiny bits of ice as they reached other moist areas in turn attract further moisture and possibly at some other place result in precipitation?

Mr. KRICK. I think the answer to that is, "Yes." In other words, any maximum that you have downwind from this type of operation would probably be a combination of tiny ice crystals that drifted down, as you suggested, plus any residual material that was present. Both things seem possible to me.

Senator ANDERSON. You realize, Dr. Krick, that this matter is becoming quite interesting because of a situation that has arisen in Washington where, like the olden days of the saloon, they are now forming into two groups called the wets and the drys.

I just noticed a clipping from Pascola, March 26, an AP story saying:

> Ed Garrick announced that 6,500 soft-fruit, hay, and bean growers would go right to the clouds in a battle with the wheat growers over rain.

They are going in and try to overseed so that between April 1 and October 15 there will be no rain. Your organization will be in attempting to seed, so that there will be rain. I wonder if that suggests to you the desirability of some type of regulation.

Mr. KRICK. It certainly does. However, Senator, I might inject this argument at this point, not an argument against proper regulation but simply the thought that these things sometimes tend to resolve themselves if you can ever find people that want to sit down and talk it over sensibly.

Now, this is very interesting because it shows that there was a lack of organizational ability on the part of the sponsoring agency that first got this program going in Washington.

They did not sufficiently consider the problems of the irrigation farmer or the irrigation farmers did not even want to discuss the

matter, but that whole thing could be pretty easily resolved and I have a hunch that it may be resolved by the conflicting groups by simply indicating to these irrigation farmers that there will be no seeding operation during times of their harvest, which is all they have ever been worrying about.

Now, last October during their bean harvest, which incidentally should not have been in October—it should have been in September—but they simply did not get around to it, so they got more rain than they wanted, and in fact they are probably more convinced that we can do a job than the wheat farmers may be, because they got particularly wet during October, which would have been a fairly wet month anyway, whether anybody had been operating or not, but if they had used weather forecasts to try to guide themselves in getting in these beans in the periods when there were no storms, which is probably fairly feasible because we cannot alter nature's sequence of weather—all we can do is operate on whatever comes along—but by a coordinated effort there and by representation on the sponsoring board of this organization they probably could have overcome these difficulties if they had gotten at it soon enough.

Now, I am afraid that if they do not resolve their problems, they are going to be disappointed because I doubt very much whether all rain in the area can be suppressed, and the first rain that falls after April 1 is going to be very disappointing to them and they will probably decide to fire these operators, and then we will be right back into it again.

I think it is in cases of that type where these groups seem to be so immature in their negotiations that they cannot settle their differences, that someone has to step in and say, "Well, now, here, this is the way it is going to be," because it seems to me it is far more harmful to cut out precipitation altogether than to increase it in a sensible way as it is required and to coordinate all these activities.

In conclusion, I agree with you completely that that is certainly a place where it may be necessary for somebody to step in and say who will do what.

Senator ANDERSON. Now, you mentioned the fact that you have been operating, running seeding operations in Mexico.

That would seem to me to indicate the impossibility of handling this only by State laws, since, if you are going to have relationships with a foreign country on any formalized basis, it has to be done through some Federal agency. Some of us wondered how you would get the cooperation, a good many of us think we are going to need, from Mexico, and perhaps from Canada, if we lack Federal action.

I am not trying to argue now the full regulatory powers that might be carried in S. 222. I am talking about the need of some Federal over-all group that might have knowledge of what is going on and be in a position to negotiate.

Senator CORDON. It seems to me, Mr. Chairman, that it might not be too difficult to regulate the activity of our own citizens, say, over in Mexico, where they are attempting to influence weather in the United States, or in Canada where they are attempting to influence weather in the United States, but we certainly run into a "toughie" if Mexican citizens begin the operation in Mexico, or citizens of Canada commence it in Canada, if we are the residual recipients of it if it happens.

Senator ANDERSON. It just occurred to me when I was reading these newspaper stories, that while the fruit growers and the wheat growers might come to an agreement in Oregon and Washington, somebody in Canada might do something that would upset all their plans or somebody operating up into Alaska in an area which may contribute weather to most of the United States might cause us some difficulty, and it seems possible that we do need some broader base than this, than just registration, perhaps, of what is going on.

The possibilities, it seems to me, are great to the southwestern part of the United States and I assume there are great possibilities to other parts of the United States. I can imagine that by the modification or slackening of violent storms, the control of hurricanes, things of that nature, that weather modification has tremendous value to all parts of the country, but to those people who are in the southwestern part of the United States the possibility of operating in Mexico or some other area off the continental limits of the United States to produce increased water in these streams is of tremendous importance.

We are faced with certain projects now with which the Senator from Oregon is very familiar, which run into the hundreds of millions of dollars on one project alone. The only reason why that project is necessary is that a normal rainfall sufficient to carry the project in the beginning now seems to have disappeared.

If by some means that could be restored, the Federal Treasury might be saved hundreds of millions of dollars on the one project and a great deal more on others. Does this not occur to you as a more practical approach, perhaps, than to concern ourselves with the entire rebuilding of all the irrigation plants in the West?

Mr. KRICK. Well, sir, I think that is definitely a possibility. I gather from the Senator's remarks that he is fairly well convinced that this is an accomplished fact. I am not so sure yet.

I think, as you will agree, there has not been a complete agreement even among the people in this profession that this can be accomplished.

I feel, therefore, everything you say is valid, but I believe the timing must be considered. At this particular time we are still in the experimental phase of this thing. I regard all of our work still as really experimental.

Now, if people want to sponsor these experiments, we are willing to undertake them but I do not think anyone has the idea yet that it is a proven thing, but we certainly have to go through a phase here where we can collect sufficient data to nail it down one way or the other, and I think we certainly must have a coordinating body somewhere to which operators such as ourselves can submit our data for an objective evaluation.

However, it seems to me that the actual regulatory action that you speak of, particularly on the international scale, is perhaps premature until we have really delineated these problems so we know just how such legislation should be framed.

Senator ANDERSON. I agree very fully with what you said about this not being an accomplished fact, and I think that justifies perhaps the conservative attitude that the Weather Bureau has taken toward it. I am not worried about the fact that they want to be convinced of this thing. I think that is all right.

Somebody has to be careful about these matters, but it does suggest to me the desirability of knowing what goes on in the entire area.

Mr. KRICK. Exactly.

Senator ANDERSON. Because you cannot decide whether there is any value to this if the experiment is not a controlled experiment, in other words.

Mr. KRICK. That is right.

Senator ANDERSON. If you had been seeding in certain areas of New Mexico and had been expecting that certain results would come from it and I had gotten a little generator of my own and persuaded a few friends to get generators and we had turned those on and you had no knowledge of what we were doing, then you have not the control over the work you are doing to which I think you are entitled. I think you are entitled to know of everyone who operates in that field and just what he sprays into the clouds.

Senator CASE. Mr. Chairman, may I ask this? Under the type of contract that you used with these associations of landowners or farmers, who has the responsibility, the legal responsibility, for any fancied or alleged damage that may occur?

Mr. KRICK. Well, I think Colonel Gillenwaters could probably answer that better than I.

Mr. GILLENWATERS. It is the same as any other overt act, Senator. Our organization is liable, the contracting agency is liable if we act in a nonprofessional or in a negligent manner, and for that very reason where the exposures are indicated by our survey, that is my responsibility to then recommend to the organization the insurance which we can provide, and we insure against those.

I say up to this point we have had no claims filed against us, but the survey indicates the type of exposure that you can expect in view of the type of weather that historically takes place in an area.

Senator CASE. Now, you have in your organization Kenneth Raetz who has been meeting with different groups of farmers in South Dakota, and I have here quite a few clippings of meetings of very great interest. The questions the Senators have been asking are the questions that grow up in a practical consideration of a project. I just want to read a paragraph or two here:

> The fact the corporation would be willing to provide its service for two such associations, one west of the Sanborn and Davison County lines, the other east, is proof the firm does not feel its operations rob downwind areas of moisture.

Then it quotes:

> Nature gets only 1 percent of the moisture in a cloud as rain. We can get only 1 percent more with our operation, so that leaves 98 percent of the moisture for anyone else.

That is what the field man said. That apparently is an answer to this fear that if we start this here, we are going to take it away from the county across the line.

"The recently advanced theory that seeding with the tiny silver iodide particles could cause cloudbursts 2,000 miles away is discounted by Raetz.

"'Recent studies by Dr. Workman of the New Mexico School of Mines show that the life of a particle of silver iodide is only 1 hour and that 98 percent of the particles are gone in the first half hour.

"'It would be impossible for the particles to travel 2,000 miles in that hour.'"

I am not trying to set up any dispute between you and your field man, but this is the representation on which these contracts are being

negotiated when the farmers raise questions: "Are you going to cause damage somewhere" or "are we going to take someone else's rain away?"

Mr. GILLENWATERS. Legal cases, Senator, are not tried on newspaper clippings.

Senator CASE. That is the representation on which these farmers are putting up money.

Mr. GILLENWATERS. I do not want to disagree with the Senator, but the newspaper quotations on rain making have raced off into the realm of fantasy and fancy in many cases.

Mr. KRICK. Let us just analyze those statements. There is nothing wrong with those statements basically because I have just indicated that in the simplest analysis probably considering the amounts of rain that nature removes from a storm which you can do artificially amounts to 2 percent, but even that of itself would probably be sufficient to indicate that you are not robbing anyone of their rightful supply of moisture.

The statement that crystalized silver iodide particles may become ineffective in a half-hour to an hour is not complete. It does not go on to say that that refers only to the release of silver iodide in direct sunlight and that is not even a proven fact.

However, the idea of the materials drifting downwind 2,000 miles and directly producing anything is probably incorrect because the diffusion in that distance would be so great that the materials would be ineffective even if they lasted that long. The chances are that they would not last that long.

They might encounter systems that they could work on if they were released in clear air somewhere upwind. I think that the difficulty here is probably not only in confused reporting but in interpretation of that reporting.

I do not see anything too invalid in those two statements if they are followed through to their conclusion.

Senator CASE. Mr. Chairman, I do not know that it should be inserted right here, but in the hearings to be published it seems to me that some of these accounts of the organization of the farmers would be valuable for reference.

Senator ANDERSON. I am going to suggest, Senator Case, since you are author of one of these bills, that you take from those items such portions as you think are pertinent and without objection they may be printed in the record at this point.

(The newspaper accounts referred to appear at the conclusion of the testimony on March 19.)

Senator CORDON. I hope these are comprehensive enough so that we will get the full import of the content.

Senator ANDERSON. In those items to which Senator Case refers, there is a statement as to how your organization operates and indicates that you come in and make a survey and study the previous weather records and that work is done by the American Institute of Aerological Research. Is that the correct statement of it?

Mr. KRICK. That is correct.

Senator ANDERSON. The research organization that makes its studies in advance upon which contracts are subsequently based.

Mr. KRICK. That is right.

Senator ANDERSON. I wanted to ask just one question. If there is an organization in the community that does not want to take part and participate in the program, your organization does make an effort to give them an opportunity to have some sort of an observer, as you mentioned in this Washington case, or put somebody in touch with the sponsoring committee. That question has been raised.

What happens to the people who are not in? Can you just briefly state what happens to them? Here in our State of New Mexico, for example, 85 percent probably of the rangeland, at least, has been signed up with your organization. What happens to the other 15? They are going to get perhaps incidental and collateral benefits that cannot be separated. You cannot pinpoint down to the very few acres, but do you make an effort in case an irrigation district is not in, to try to bring them into touch with rain makers, with the group that is actually going to supervise the work?

Mr. KRICK. That has been our recommendation, that in any of these areas where there are diverse interests, we feel that it is essential that the sponsoring agency have representation on their board not particularly of the geographical or political districts in the area, but of the diverse interests that may be affected by the operation in the area. It has been our recommendation that that be carried through.

Now, we do not have the authority to see that it is carried through, but it is cases where it is not carried through that differences arise as have arisen in Washington. We were aware of that problem and made the recommendations long, long ago that they resolve their problem with these people or they might find themselves in difficulty.

We also reserve the right to cease operations if we so desire even though the situations may arise that are favorable, and if this thing looks as though it might be a damaging proposition, we have the authority to cease those operations, as we did last summer, so that any damaging effects would not therefore be due to any operations.

Senator ANDERSON. One other question along that same line. What is your attitude then toward individuals who may be operating aircraft in seeding or generators. Is there any basis upon which you can work out cooperative arrangements of any kind with those individuals?

Mr. KRICK. We certainly will make the effort in the cases where we are apprised of the situation. Thus far that problem has not arisen.

Either the operators were operating equipment that in our opinion did not mean anything, or they were operating in areas which did not affect our program materially, so the problem has yet to be presented.

Senator ANDERSON. But in the absence of legislation it would seem to me quite vital that there be some sort of cooperative arrangements between the groups that are working in this field.

Mr. KRICK. I think that is one of the objectives of the so-called national association which embodies in the inclusion of its membership all of these sponsoring agencies.

I think it is their purpose to see that the programs are properly coordinated and to try to discern improvements that can be made in operations and to discern who is a good operator and who is a bad

operator, and so on. There is a mechanism established by that organization to cope with many of these problems.

I think a lot of the people that are sponsoring these programs would like to feel that they would still be free to carry on at their own expense the experiments that they have sponsored and to try to regulate themselves.

Now, obviously, if they fall down on the job, somebody is going to have to step in, but I do not think that has any bearing upon the basic problem here of getting some independent objective coordinating agency that everyone can submit their experiments to and see that they are properly evaluated to get the facts on this thing. I certainly endorse that sort of agency.

Senator ANDERSON. You people are operating in the southeastern corner of Arizona where I believe the Salt River Valley group is operating generally in the headwaters of the Salt River, not too far apart from each other.

Mr. KRICK. Yes; but the way the storms develop there is very little relationship or very little conflict in those two operations because the air streams that they use do not enter the region where we are operating, so there is no conflict there at all.

Senator CASE. Just one question, Mr. Chairman. Having in mind what you said about the possibility that you would be getting some water from the Gulf of Mexico and that that might contribute to solving the water problem in the Southwest and thereby saving prospective millions of dollars in irrigation facilities, I would like to have your opinion on the possibility of the benefits by getting moisture that may be drawn up in clouds from the chain of dams which the Government is now engaged in building on the Missouri River.

There will be a chain of those dams extending from about Sioux City, Iowa, into Montana, ranging in capacities from about 6 million acre-feet to 21 or 22 million acre-feet. One of the dams will have a body of water 200 miles long. Those will run through the central part of South Dakota and through the central part of North Dakota, extending on into Montana.

The Government plans are at present to build some irrigation projects which are rather expensive and provisions for canals and distribution systems, leveling of ground, and so forth, to make irrigation possible.

Is it at all possible that the potential of increased precipitation by reason of more cloud formations over those lakes will provide the margin of additional water that areas of 15- to 18-inch normal rainfall would not need an irrigation distribution system?

Mr. KRICK. I think, if I understand the question correctly, you wish an expression of opinion as to whether these bodies of water by evaporation into the atmosphere would contribute to natural rainfall processes sufficiently to offset——

Senator CASE. Not wholly, but if by evaporation of the atmosphere they produce cloud formations which you can precipitate the rain from, will they eliminate the necessity for building irrigation systems?

Mr. KRICK. The answer to that, in my view, would be "No," because the cloud formations that must be used for this work are dependent upon much larger scale phenomena in the atmosphere than anything that could be produced by such a local effect as a small lake or reservoir.

In other words, the air stream in which you would operate coming up from the Gulf would actually get its moisture supplied from a trajectory over thousands of miles of ocean and the Gulf of Mexico before entering the continent.

There might be some evaporation from the soil, grasses, trees, and so on, and lakes and reservoirs, as it passes northward, but by far the largest amount of precipitable water is already within the air stream before it ever reaches the United States, so the contribution that the works you refer to would make to that over-all moisture content would be negligible.

Senator CASE. The one dam, the largest dam, will range from about a half a mile to 6 miles wide and 200 miles long.

Mr. KRICK. If the atmosphere crossed that dam even along its longest length, the water trajectory of the area, as you say, would be around a mile or so, which would not permit it to pick up any appreciable moisture. I think probably a good analogy would be the case of Lake Mead in connection with Boulder or Hoover Dam.

There is really no appreciable influence upon the basic weather patterns that can be discerned from the influence of that body of water. It usually takes a body of water about the size of one of the Great Lakes to have any particular influence upon the air streams that are moving across it, so I think most meteorologists would agree that there would be practically no contribution.

Senator CASE. No heavier dews?

Mr. KRICK. Well, there might be a heavier dew in the immediate vicinity of the body of water through some cooling effects, but even that seems unlikely to me because dews are nocturnal and the influence of a body of water would be to increase the temperature in the immediate vicinity during the night, so I feel there is really no influence at all that would have an effect upon the basic weather patterns of the area by artificial works of that type.

Senator ANDERSON. I think that is the experience of the State of Texas when the small dams and some of the larger ones were constructed there. They found it had a negligible influence.

It is close to lunch. We would like to have a little session with you in executive session this afternoon, Dr. Krick, if that would suit you.

Mr. KRICK. That would be satisfactory.

Senator ANDERSON. I think we will recess now until 2:30 and we will go into executive session at that time.

(Whereupon, at 12:55 p. m., the hearing was adjourned.)

APPENDIX

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., July 7, 1949.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate.

MY DEAR SENATOR O'MAHONEY: I am glad to comply with your request for an expression of the views of this Department on S. 1300, a bill to conserve and increase the Nation's water resources, for promotion of irrigation in arid areas, by research and demonstration of practical means of producing, from sea or other saline waters, water suitable for beneficial consumptive use, and for other purposes.

We recommend enactment of the bill in question.

The benefits to millions of our citizens that would follow successful development of economically feasible means of producing, from saline waters, water of quality suitable for beneficial consumptive use would be incalculable. The proposed large-scale distillation of the salt water of our oceans is an opportunity that challenges not only the imagination, but the scientific resources of the Nation.

Water shortages are acute throughout many areas of the West today, where many thousands of acres of irrigated land are being kept in production only through serious overpumping of the existing ground water. Thousands of acres of fertile soil are awaiting only irrigation water to be transformed into highly productive farms that will support greatly increased population in rural and urban areas. The expansion of irrigation in the West will increase the purchasing power and provide markets for manufactured and other products. There is, therefore, a national and urgent need for constructive action.

Water shortages which already exist or are threatened in a large number of industrial and urban areas will affect the health of millions of city dwellers, the safety of billions of dollars in property values, and the general welfare not only in the West but throughout the country.

In many of these areas the existing urban and irrigated agricultural developments can be maintained over a period of years only if additional water supplies are secured. Similar conditions exist in the Virgin Islands and in other insular possessions of the United States.

Through the discovery of economical methods for wholesale purification of ocean waters, new frontiers would be opened for development not only in the western United States but throughout the world.

Pumping from ground water for irrigation in some of the most highly productive areas in California, Arizona, and New Mexico during the past few years has been at rates more than double the safe yields as estimated by the United States Geological Survey. In many localities in those three States, the groundwater table has been receding in recent years from 2 to 12 feet per year because of over-pumping. The same situation exists, although to a lesser degree in other Western States.

Municipal water shortages have also occurred, such as at Santa Barbara, Calif., during last summer's drought. In the Los Angeles, San Diego, and San Francisco-Oakland metropolitan areas of California, between 1940 and 1947, the population increased from 4,625,000 to 6,382,000, a gain of approximately 38 percent. Estimates forecast a 1960 population for the three areas of 8,250,000, a further gain of approximately 30 percent over the 1947 figures. In case of another national emergency, the need for additional domestic and industrial water supplies in these and some of the other western cities might well be immediate and pressing. Such a need might have to be met at the expense of irrigation as, for example, a similar problem was solved at El Paso, Tex., a number of years ago by taking 1,200 acres of irrigated lands of the Rio Grande project out of production so that the water rights of those lands could be transferred to the city.

The Bureau of Reclamation this year started investigations to determine if it would be feasible to divert and transport to California a small part of the 150 million acre-feet of water of the Columbia River Basin that now pour into the Pacific Ocean each year. This may or may not be feasible from engineering and economic standpoints. The Nation cannot afford to overlook the possibility of obtaining an urgently needed water supply at least in part from some other source, such as through the distillation of sea water.

Some of our large eastern seaboard cities are also concerned about their water supply. Pumping wells in Kings and Queens Counties, Long Island, N. Y., to augment the water supply for the New York metropolitan area, over many years, in addition to wells for industrial purposes, had lowered the water level at the western portion of the island to as much as 30 feet below sea level. In 1946, sea-water encroachment into the ground water under the Borough of Brooklyn (Kings County) had advanced to the point where it became necessary for the city to condemn and shut down pumping from all public supply wells of the New York Service Corp. in the Flatbush area. These 35 wells had been producing 26,000,000 gallons of water per day.

Since shutting down those wells, the ground-water level has recovered until today it is back to sea level or above throughout most of the south Brooklyn area. Loss of this supply, however, has increased the seriousness of New York's water shortage, which it is expected will become acute prior to completion of the Delaware water supply system, now under construction. This new system, estimated to be completed about 1954 at a total cost of $440,000,000, is expected to add 540 million gallons per day of dependable yield to the city's water supply.

Providing New York City with adequate water is, however, a never-ending problem. Before completion of the Catskill system, it was necessary for the city's engineers to start investigations for new and additional sources. So it is now with the supply being developed from the upper Delaware River watershed. Unless the rate of increase in consumption drops off materially, it is anticipated that additional water will be required shortly after the full yield of the Delaware sources becomes available. Where such additional water might be obtained, at a price that is not entirely prohibitive, is questionable. Distillation of sea water might provide an answer.

During World War II industrial research and experimentation resulted in greatly increased efficiencies in connection with distillation units for shipboard use, and for establishments ashore for the production of fresh water from sea water, particularly for use on South Pacific islands where it was expected there would be very short supplies of surface or underground water for use of the United States troops. The units that were most efficient at the start of the war were capable of producing 250 gallons of fresh water per hour with a water-to-fuel (Diesel oil) ratio of approximately 24 to 1.

Up to the present, the efforts to develop distillation processes suitable for large water supplies for metropolitan areas or for irrigation use have been severely limited. Within the past 5 years, however, developmental research has been continued on a small scale and today several companies in the United States are manufacturing vapor compression distillation units varying in rated capacities from 60 to 4,000 gallons of distilled water per hour.

It is estimated by the manufacturers that the largest of these units, from which production is still quite small in comparison with needs for large municipalities, or for irrigation, have been improved to such an extent that their water-to-fuel ratio is approximately 200 to 1, and the cost of distilled water produced, including depreciation, fuel, cleaning, and all other operating costs might be as low as 55 cents to $1.50 per 1,000 gallons. This is equal to approximately $180 to $490 per acre-foot.

These costs might be compared with the annual water charges of $35 per acre-foot that the city of Santa Barbara will pay for a municipal supply from the Bureau of Reclamation project on Cachuma Creek, Calif., and $28 per acre-foot that the city of Dickinson, N. Dak., will contract to pay for municipal water from one of the units of the great Missouri River Basin project.

Other than in those instances, the highest prices paid for municipal water, of which I am aware, were at Tucumcari, N. Mex., where a temporary contract provided water to the city at $48 per acre-foot, which will be reduced after installation of a permanent system, and in some localities in the Central Valley of California where charges might reach a maximum of $20 per acre-foot.

It is evident that the cost of distilled water is still much too high for municipal use, except perhaps in a few isolated or emergency situations, and that distillation

by today's known methods is entirely infeasible for providing water for irrigation use, both from the standpoint of cost and production quantities. It should be noted, however, that since the beginning of World War II, the efficiency of the largest distillation units has been increased eight times.

With this as encouragement, the Department of the Interior believes that additional developmental research on a large scale is warranted. The problem with which we are confronted is to develop, through extensive research and experimentation, distillation plants with 500 times the capacity and 50 times the efficiency of the largest units manufactured today. However, it is entirely possible that some other method, such as electronic distillation, electrolysis, chemical reaction or chemical neutralization, may prove to be the most desirable solution to the problem. Developments in these other fields have also been rapid during the last few years. It is likely that utilization of the salts and other solid materials in the water will be necessary to a satisfactory method of producing water at a cost that will be conducive to widespread use of the salvaged water. Considerable research should be performed before any attempt is made to state what method will be most desirable.

We recommend an aggressive attack on the critical water supply problems of the Nation in the same manner and in the same spirit that were employed in the wartime research and development programs.

In view of your request for an immediate report, there has not been time for the usual clearance with the Bureau of the Budget. Accordingly, I cannot advise regarding the relationship of the proposed legislation to the President's program.

Sincerely yours.

OSCAR L. CHAPMAN,
Acting Secretary of the Interior.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington D. C., April 12, 1950.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

MY DEAR SENATOR O'MAHONEY: In my report of July 7, 1949, to your committee, I recommended enactment of S. 1300, a bill to conserve and increase the Nation's water resources, for promotion of irrigation in arid areas, by research and demonstration of practical means of producing, from sea or other saline waters, water suitable for beneficial consumptive use, and for other purposes. I was unable to advise you at that time concerning the relation of the proposed legislation to the program of the President.

I am now in receipt of a letter, dated March 20, from the Acting Director of the Bureau of the Budget, in which he says:

"* * * I am authorized to inform you that the President desires to have the Department of the Interior take the leadership in necessary research, experimentation, and demonstration designed to develop economic means of producing from sea water or other saline waters, water which is suitable for agricultural, industrial, municipal water supply, and other beneficial consumptive uses.

"The President agrees that statutory authority for the necessary work should be sought, and requests you to take the lead on behalf of the administration in recommending early enactment by the Congress of S. 1300 with certain amendments discussed in the succeeding numbered paragraphs."

A copy of Acting Director Lawton's letter is attached.

In view of the President's endorsement of the principle of S. 1300 and of his tentative inclusion in the budget for the fiscal year 1951 of $500,000 for carrying out work along the lines proposed in S. 1300, permit me to urge amendment of that bill to conform to the recommendations of the Bureau of the Budget and its speedy enactment as so amended. To aid your committee in its consideration of the amendments recommended by the Bureau of the Budget, there is attached a copy of the bill with appropriate changes in its text indicated in the usual manner.

Please call upon me if I can be of any assistance to you or your committee in this matter.

Sincerely yours,

OSCAR L. CHAPMAN,
Secretary of the Interior.

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EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington, D. C., March 20, 1950.

The honorable the SECRETARY OF THE INTERIOR.

MY DEAR MR. SECRETARY: This will acknowledge receipt of your letter of January 9, 1950, addressed to me and your letter of the same date forwarded to the President through this office. I am authorized to inform you that the President desires to have the Department of the Interior take the leadership in necessary research, experimentation, and demonstration designed to develop economic means of producing from sea water or other saline waters, water which is suitable for agricultural, industrial, municipal water supply, and other beneficial consumptive uses.

The President agrees that statutory authority for the necessary work should be sought, and requests you to take the lead on behalf of the administration in recommending early enactment by the Congress of S. 1300 with certain amendments discussed in the succeeding numbered paragraphs.

1. Both the title of the bill and the introductory language of section 1 stress the production of water for irrigation purposes, in fact to such an extent that it can be argued that the language used restricts the purposes of the bill. The President feels that both the title and section 1 of the bill should be broadened so as to bring in the concept that the purposes are to produce economic means for the large-scale production of water for agriculture, industry, municipal water supplies, and other beneficial consumptive uses. Irrigation may be only one of the agricultural uses ultimately to be involved.

2. While, without doubt, the Bureau of Reclamation has a broad interest in the large-scale distillation of salt water, this Bureau should not be singled out in the authorizing legislation as the principal agency of the Department of the Interior for the conduct of necessary work. All authority should be vested in the Secretary of the Interior, who should be further authorized to discharge his responsibilities through such agencies of the Department as he may deem appropriate. This device also has advantages in terms of interagency collaboration and in more effective communication on the problems of basic scientific research which may be involved. In solving them, it may, perhaps, be more effective to use scientific personnel and facilities of the Geological Survey rather than those of the Bureau of Reclamation.

3. There is no apparent reason for the authorization of more than one demonstration plant at this time. The bill should specifically authorize the Secretary to choose the location of the demonstration plant.

4. The Secretary should be authorized to call upon other Federal agencies for such assistance as they may be prepared to provide and such agencies should be authorized to provide assistance subject to reimbursement by the Secretary of the Interior for the cost of assistance so provided. Existing law (sec. 601 of the Economy Act) is broad enough to permit such collaboration by other Federal agencies, but it seems desirable to have the legislation inclusive at this point.

5. The authorization in section 3 of S. 1300 to construct transportation facilities is unnecessary at this time in view of the authorization contained in section 1. It is also felt that this authorization is so broad as to be subject to misinterpretation. Its elimination from the bill should be sought.

6. The annual reports of the Secretary should be made to the President as well as to the Congress.

7. In view of limiting the bill at this time to authorization of one demonstration plant, the authorization for an appropriation of $50,000,000 appears to be too great. It is suggested that this authorization be changed to $25,000,000, without prejudice to further requests for an increase in this limitation should such become necessary.

In accordance with your request, the President has sent letters to the Secretary of State, the Secretary of Defense, the Secretary of Agriculture, the Secretary of Commerce, the General Services Administrator, the Chairman of the Federal Power Commission, and the Federal Security Administrator, requesting their cooperation with you. A copy of each of these letters is attached.

Very truly yours,

F. J. LAWTON, *Acting Director.*

(S. 1300, 81st Cong., 1st sess., with proposed amendments by Department of the Interior shown in italics.)

A BILL To [conserve and increase the Nation's water resources, for promotion of irrigation in arid areas, by] *provide for* research *into* and demonstration of practical means *for economical production*, [of producing,] from sea or other saline waters, *of* water suitable for *agricultural, industrial, municipal and other* beneficial consumptive [use,] *uses*, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the urgent *acute* shortage of water [for irrigation] in *the* arid areas *of the Nation and elsewhere* and the excessive use of underground waters throughout the Nation [for industrial and domestic use], it is the policy of the Congress to provide for the development of economically feasible means of producing from sea water, or *from* other saline waters, water of quality suitable for *agricultural, industrial, municipal, and other* beneficial consumptive uses. To this end, the Secretary of the Interior, acting through [the Bureau of Reclamation and] such [other] agencies *of the Department of the Interior* as he may deem appropriate, is authorized to construct, maintain, and operate, [one or more] *a* demonstration plant[s], *at a suitable site selected by him, together* with all facilities and accessories for the manufacture, purification, storage, [transportation,] and distribution of the resulting water and other products. [Such] *The* plants, accessories, and facilities shall be of such [capacities] *capacity* as will furnish all cost and engineering data necessary to determine the feasibility of the development of such production[, transportation,] and distribution, on a large-scale basis, for the purpose of conserving and increasing the water resources of the Nation.

SEC. 2. In order to carry out the purpose of this Act, the Secretary of the Interior is authorized—

(a) to conduct laboratory research and development work, and with [pilot] *the demonstration* plant[s] and other facilities to make careful engineering studies to ascertain the lowest investment and operating costs, and to determine the best plant designs and conditions of operation;

(b) to study methods for the recovery and marketing of byproducts resulting from and incident to the production of water as herein provided for the purpose of ascertaining the possibilities of offsetting the costs of water production in any area by the commercial utilization of such products;

(c) to acquire, by purchase, license, lease, or donation, secret processes, technical data, inventions, patent applications, patents, licenses, land and any interest in land (including water rights, easements, and leasehold interests), plants and facilities, and other property or rights: *Provided*, That the land or other property acquired hereunder shall not exceed that necessary to carry on the experiments and demonstrations for the purposes herein provided;

(d) to engage, by contract or otherwise, chemists, physicists, engineers, and such other personnel as may be deemed necessary, and any educational institution, scientific organization, or industrial or engineering firm [deems] *deemed* suitable to do any part of the research or other work; [and]

(e) to cooperate with any other Federal, State, or municipal department, agency, or instrumentality, and with any private person, firm, educational institution, or other organization in effectuating the purpose of this [Act.] *Act; and*

(f) to request other Federal departments, agencies, and instrumentalities to provide assistance in carrying out his functions under this Act, which assistance such departments, agencies, and instrumentalities are hereby authorized to render, and to advance to them funds required to render such assistance or reimburse them for costs incurred in so doing.

SEC. 3. The Secretary of the Interior is authorized to dispose of all water and other products produced as a result of its operations under this Act pursuant to regulations to be prescribed by him[, and may construct such transportation facilities as may be needed for this purpose]; and the Secretary shall have authority to grant, under such terms as he may consider appropriate, licenses under patent rights acquired under this Act: *Provided*, That such licenses are consistent with the terms of the agreements by which such patent rights are acquired. No patent acquired by the [Bureau of Reclamation] *United States* under this Act shall prevent any citizen of the United States, or corporation created under the laws of the United States or any State thereof, from using any invention, discovery, or process covered by such patent, or restrict such use by any such citizen or corporation, or be the basis of any claim against any such person or corporation on account of such use.

SEC. 4. All moneys received for products of the plants and for royalties and licenses under this Act shall be paid into the Treasury as miscellaneous receipts.

SEC. 5. The Secretary of the Interior shall make reports to the *President and the* Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act. The reports shall include suitable recommendations for further legislation.

SEC. 6. The Secretary of the Interior may issue rules and regulations to effectuate the purposes of this Act.

SEC. 7. There [is] *are* authorized to be appropriated, from any funds in the Treasury not otherwise appropriated, such sums, not to exceed [$50,000,000.] *$25,000,000,* as the Congress may from time to time deem necessary to carry out the provisions of this Act.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., June 23, 1950.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

MY DEAR SENATOR O'MAHONEY: I am glad to comply with your request for an expression of the views of this Department on the amendments dated January 4, 1950, intended to be proposed by Senator Downey to S. 1300, a bill to conserve and increase the Nation's water resources, for promotion of irrigation in arid areas, by research and demonstration of practical means of producing, from sea or other saline waters, water suitable for beneficial consumptive use, and for other purposes.

Subject to the qualifications hereafter expressed and to the further amendments there suggested, this Department recommends adoption of the proposed amendments.

The need for additional fresh-water supplies in the arid West and in many water-short municipalities in the East is now acute. The president in his message of January 3, 1950, on the budget of the United States for the fiscal year ending June 30, 1951, page M-66, stated:

"Experience in recent years has shown that it may not be possible to meet the shortages of water, which are a threat in some areas, through our extensive water-resource programs. I recommend, therefore, that the Congress enact legislation authorizing the initiation of research to find means for transferring salt water into fresh water in large volume at economical costs."

Discussion of the water shortage was set forth in some detail in this Department's report of July 7, 1949, expressing its views on S. 1300, with relation only to producing additional water from sea or other saline waters. The proposed amendments would include the artificial derivation of precipitation from the atmosphere as a second new source of additional water to be investigated and developed.

Studies made by the Army-Navy-General Electric organization known as "Project Cirrus," by the Weather Bureau, and by numerous other Government, university, and private investigators all point to the conclusion that it is possible, under certain conditions not completely defined as yet, to cause some rainfall or snowfall artifically.

From the present indications, it appears that the cost of producing rain or snow artificially may be remarkably low once the research and experimental work has been completed. The benefits of such artificial precipitation, if practicable, are obvious. Primarily they would consist of firming up water supplies for presently irrigated land and increasing the extent of irrigated acreage of potential projects; increasing municipal supplies for water-short cities and towns; improving forests and ranges; and increasing power production.

Aside from the somewhat questionable possibility of causing rain to fall directly on water-short croplands during the growing season, research in cloud physics and artificial precipitation has now advanced sufficiently to suggest that it may be possible to affect the total annual precipitation in some areas by artificial means. It appears possible, for instance, that the winter snow pack in certain mountainous areas where atmospheric conditions are favorable might well be increased in this way. If it should become possible by artificial means to add even a small amount of snow each day throughout the winter, the total quantity of water available for existing or potential irrigation, municipal water supply, and power production would be increased. Much basic and applied research, and field demonstration,

will be needed before it can be told with certainty whether this can be done on a practicable scale and at costs sufficiently low to justify the results gained.

Quite aside from the direct benefits that might accrue, the increased runoff from the artificially produced rain or snow may require changes in plans for future projects and even in designs of dams and other works. If this additional water is to become available, its amount and location should be determined at the earliest possible date so as to avoid costly alterations of structures now being planned and designed by the Bureau of Reclamation. It is possible that some modification of existing structures may also be necessary. It is important, therefore, that work in artificial precipitation in the West be integrated with the Bureau's present operations and with all future project plans.

In lieu of the proviso proposed to be inserted on page 4, line 3, the following is suggested: "*Provided*, That any runoff resulting from precipitation created artificially under the authority granted in this Act shall be considered as a part of the natural stream flow and shall be available for use in the same manner as other natural accretions to the stream flow."

Our reason for so suggesting is this: If it is found possible to increase the precipitation on a watershed, and thus the runoff from that watershed, it will be impossible to separate that runoff from that which would have occurred naturally. Some watersheds which might be affected may be those draining into existing Interior Department reservoirs and irrigation systems in which water is transported, through canals, tunnels, etc., to points of use. New works which may be constructed by the Secretary of the Interior may likewise impound runoff from artificial as well as natural precipitation. While the plans and designs for such projects might be made on two alternate bases—one with and one without artificial precipitation—there would remain no physical means by which the two types of water could be identified and separated once they were intermingled in the stream. For the sake of simplicity in administration of water rights and to avoid legal entanglements involving ownership or damage claims, runoff from artificially induced precipitation should, at least for the present, be treated as if it were of natural origin, and therefore available to all users under existing State and Federal laws.

In addition to this substitute for one of the amendments to be proposed by Senator Downey, the following amendments to the text of S. 1300 itself are, I believe, desirable in order that the purpose of Senator Downey's amendments may be fully carried out:

(*a*) For lines 4 to 9, inclusive, on page 2 of S. 1300 substitute the following: "to construct, maintain, and operate facilities (including not more than one demonstration plant) to determine and to demonstrate the feasibility of producing water as aforesaid and for purifying, storing, transporting, and distributing the water and byproducts derived from the operation of such facilities. Facilities constructed and operations undertaken pursuant to this Act shall be on a scale sufficient to determine".

While the language now appearing in this portion of S. 1300 is appropriate for operations relating to production of fresh water from sea water and other saline waters, it is not well adapted to the artificial precipitation problem.

(*b*) On page 2, line 16, strike out the word "laboratory" for the same reason.

(*c*) On age 3, line 17, strike out the word "and"; at the end of line 22 on that page substitute a semicolon for the period and insert the word "and"; and add a new paragraph thus:

> "(f) to pursue on the ground or, any provisions of law or administrative regulation to the contrary notwithstanding, in the air operations for producing water from the atmosphere (including cloud formations)."

This addition is recommended in order to overcome any possibility that such a prohibition as that contained in the Civil Air Regulations which provide that "No person piloting an aircraft shall permit anything to be dropped from an aircraft in flight which might create any hazard to persons or property" (14 C.F.R. (1945 Supp.) 43.408) would be applied to operations undertaken pursuant to this act.

(*d*) Add a new section to the bill reading thus:

"The acts and omissions of any person or corporation who, in accordance with the terms of a contract with the United States entered into under the provisions of this Act, carries on operations for the artificial inducement of precipitation shall, with respect to third parties who are or may be adversely affected by precipitation so induced or by other meteorological phenomena caused by such inducement or attempts thereat, be deemed the acts and omissions of the United States and shall be governed by the law applicable to the same, and

the Secretary of the Interior is hereby authorized to provide in any such contract that the United States shall indemnify the contractor against liability on account of claims (including reasonable expenses of litigation and, when approved in advance by the Secretary, compromise or settlement of such claims) made by third parties as hereinbefore described, and any contract so providing shall also contain appropriate provisions for notice to the Government of suits or actions filed, or claims made, against the contractor with respect to any alleged liability to which the indemnification provisions relate and for control of or assistance in the defense of any such suit, action, or claim by the Government at its election."

It is our understanding that commercial firms have been reluctant, and in some instances have refused, to enter into contracts with Government agencies calling for experimental in-flight work related to artificial inducement of precipitation without an undertaking on the part of the Government to indemnify them against liability arising from their acts in connection therewith. Although the legal questions that may arise in this connection are far from settled (for discussion of these questions, see Ball, "Shaping the Law of Weather Control", 58 Yale L. J. 213 (1949); Ward, "Weather or Not—The Navy May Pay for Rain", JAG (Navy) Journal, October 1949; Brooks, "The Legal Aspects of Rainmaking", 37 Calif. L. Rev. 114 (1949)), such a provision as the one suggested above appears to be a minimum requirement for carrying on certain types of experimental work in artificial precipitation through other than the Government's own facilities.

The Bureau of the Budget has advised that there is no objection to the submittal of this report to your Committee.

Sincerely yours,

OSCAR L. CHAPMAN, *Secretary of the Interior.*

STATEMENT OF AMERICAN METEOROLOGICAL SOCIETY, BOSTON, MASS., ON WEATHER MODIFICATION AND CONTROL, MAY 3, 1951

The council of the American Meteorological Society, representing the meteorological profession, in cognizance of the current public interest in weather modification and control has adopted the following statements as best representing the present state of knowledge in this field:

1. The seeding of supercooled clouds with dry ice, silver iodide, and similar materials will usually convert at least a portion of the cloud to ice crystals.

2. The seeding of relatively thin, supercooled layer clouds may open holes or valleys in the cloud deck but little rain or snow will result.

3. The seeding of small, inactive cumulus clouds will usually result in the partial or complete dissipation of the clouds without the release of any significant amounts of rain or snow.

4. At best, seeding can be expected only to trigger the release of precipitation from existing supercooled clouds. The release of substantial amounts of precipitation by either natural or artificial means requires the preexistence of moist air currents and of cloud-forming processes.

5. The weather conditions which appear to be most favorable for the artificial release of rain or snow are thus very much the same as those requisite for natural rainfall. For this reason it is extremely difficult to determine whether or not the results of a single seeding experiment are favorable. Scientific knowledge of the physical processes by which rain and snow are formed has not advanced to the point where it is possible to predict the results of seeding rain clouds nor to prescribe, with any certainty, the most favorable conditions for such seeding.

6. There is very little evidence and no present scientific basis for the belief that we now possess the ability to modify or control the weather and climate of a major portion of the country.

7. Under certain conditions weather modification on a relatively small scale, such as the production of local showers, protection from frost and the local dissipation of fog is known to be possible. Further research may prove that it is possible to reduce the incidence of hail in localized areas.

8. Definitive answers to the questions left unresolved in paragraphs 5, 6, and 7 can be expected to come only from research in cloud physics and from well-designed experiments conducted by personnel with detailed knowledge in cloud physics, synoptic meteorology, and statistics. In view of the potential value of any techniques for the control or modification of weather it is of the utmost importance that such experiments be furthered.

FIGURE 1. PRECIPITATION GAUGING STATIONS

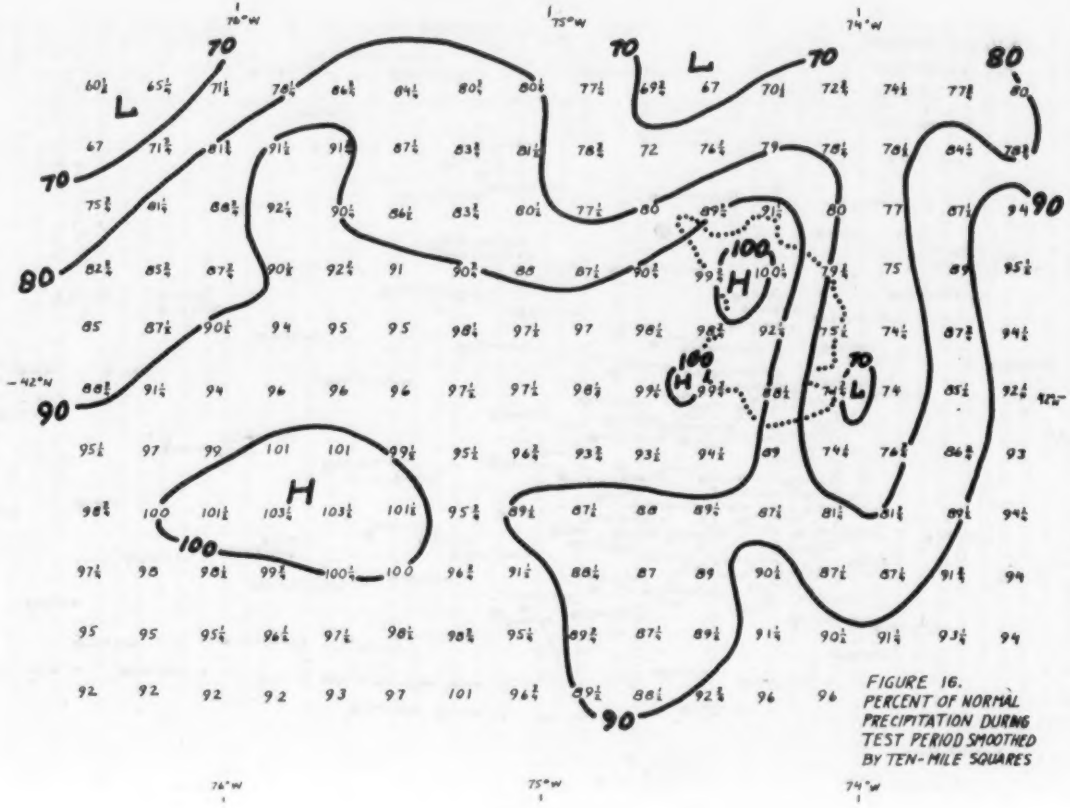


FIGURE 16.
PERCENT OF NORMAL PRECIPITATION DURING TEST PERIOD SMOOTHED BY TEN-MILE SQUARES

FIGURE 17.
PRECIPITATION ANOMALY IN INCHES DURING TEST PERIOD, AFTER U. S. WEATHER BUREAU MAPS

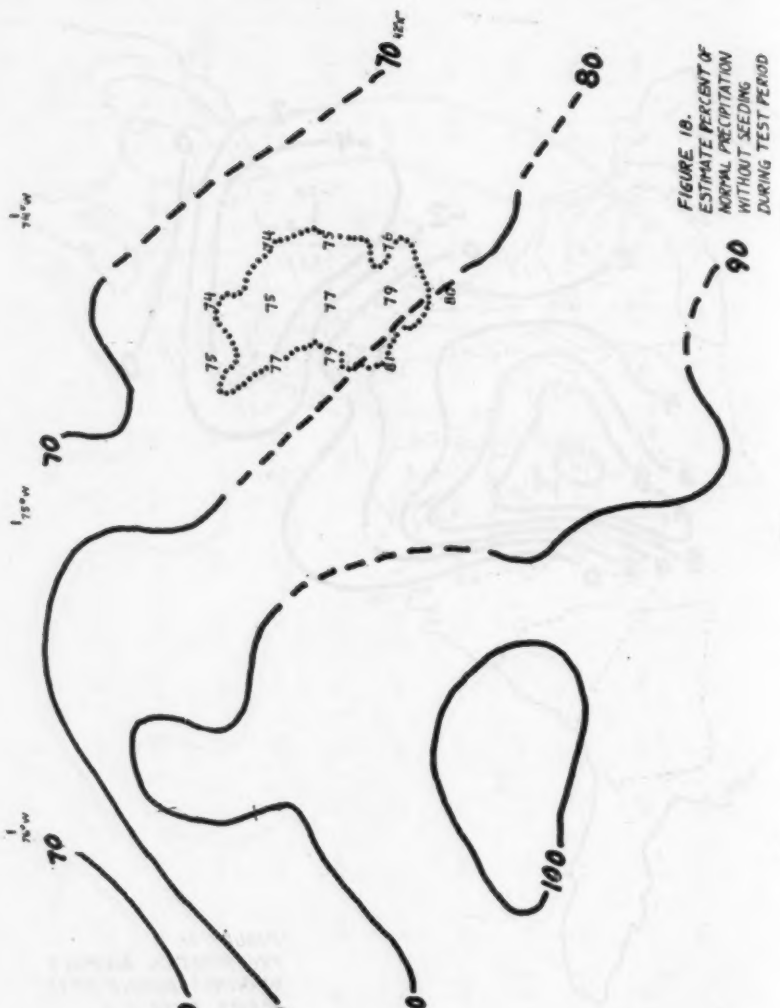


FIGURE 18.
ESTIMATE PERCENT OF NORMAL PRECIPITATION WITHOUT SEEDING DURING TEST PERIOD

Some Evaluations of Sustained Cloud Seeding Operations

(By I. P. Krick and T. B. Smith, American Institute of Aerological Research—A paper presented at the thirty-second annual meeting of the American Geophysical Union, Washington, D. C., April 30, 1951)

Extensive cloud-seeding experiments have been conducted by the Water Resources Development Corp. in various western sections of the country during the past year. Sufficient precipitation data have now become available for analysis from a portion of these operations and certain preliminary evaluations are presented in the following paragraphs.

These seeding experiments differed in a number of major respects from those reported in the literature to date:

1. Seeding was conducted over extensive regions amounting to a maximum of 9,000,000 acres in the largest operational area. Seeding over these broad areas was carried out solely through the use of silver iodide generating equipment located at ground levels. In this way the air stream passing over the operational area was impregnated with silver iodide crystals in contrast to the more common procedure of seeding individual clouds.

2. Operation of the equipment was under close meteorological supervision in order to target the seeding effects over the desired area as effectively as possible. This required a considerable amount of flexibility in operating locations under the wide variety of weather conditions experienced.

3. Seeding was conducted only at every favorable weather opportunity over a period of several months for each operating area. As indicated by previous investigators, favorable weather opportunities usually coincide with those meteorological conditions which might reasonably be expected to produce some rainfall without seeding.

From the nature of the experiments during the past year, consisting of seeding during each favorable opportunity over an extended period of time, the results of the operations lend themselves to an investigation of the cumulative effect on monthly precipitation values which may be produced by sustained cloud seeding. Since the extent of this effect is currently a controversial question, the evaluations presented in this report have been designed primarily to indicate the possible magnitude of the effect of seeding on total monthly precipitation.

During the period of July to December 1950, experiments were conducted in northeast New Mexico (July, August, and a portion of September), southeast Colorado (August, September, and a portion of July) and in the tricounties area of Oregon (Morrow, Sherman, and Gilliam Counties—October, November, and December). As a consequence, a total of seven monthly evaluations were available for analysis, representing the only experimental results when seeding operations were conducted for a major portion of the month. Due to the delay in receipt of complete precipitation data no experiments in 1951 have been fully analyzed.

In the evaluation of total monthly precipitation amounts falling in the seeded area, an attempt has been made to segregate rainfall increases due to seeding from the amounts which might have occurred from natural causes. This has been accomplished through comparisons with outside or control areas. In each case the chosen control area was upwind from the generators affecting the seeded area in order to eliminate any possible influence on the rainfall of the control stations. Selection of rainfall stations in the control area which would provide proper comparisons with the seeded area was accomplished by correlation techniques. Separate correlations were calculated between monthly rainfall amounts at various stations in the control area with an average of the monthly precipitation amounts occurring at all long record rainfall stations within the seeded or target area. Final selection of the control stations to be used was determined entirely from the magnitude of the computed correlation coefficient for each individual station. Total years available for the correlation analysis ranged from 23 to 37.

In order to smooth out a portion of the random fluctuations in rainfall amounts and thereby improve the correlation between control and target areas it was considered desirable to group the rainfall in the control area into a single parameter which might then be similarly correlated with average monthly rainfall amounts in the target area. This was accomplished in two separate ways, by using an arithmetical average of the rainfall values at the various control stations and through the use of multiple correlation techniques. The latter method provided a computed rainfall value which would be expected to occur in the target area on the basis of the established interrelationship between the control and target areas. Since the multiple correlation analysis provided a slightly higher relationship

between target and control areas, that method has been adopted in the following analysis. Both methods yielded similar results when applied to the 1950 data. Having established the interrelationship between target and control areas for past years when no seeding occurred, 1950 rainfall amounts are investigated and compared with the occurrences noted in past years.

The following table gives an example of the geographical distribution of the target and control stations as described in the foregoing paragraphs:

TABLE I.—*Locations of target and control stations, tricounties, Oregon, December 1950*

Target stations:	Control stations:
Arlington, Oreg.	Winthrop, Wash.
Condon, Oreg.	Seattle, Wash.
Heppner, Oreg.	Salem, Oreg.
Kent, Oreg.	Medford, Oreg.
Mikkalo, Oreg.	Lakeview, Oreg.
Morgan, Oreg.	
Moro, Oreg.	
Wasco, Oreg.	

Figures 1 to 7 show the results of the multiple correlations for all of the months when such analyses could be undertaken. All past years used in the correlations are plotted on the charts in order to show the variability about the regression line. Any point falling to the right of the regression line indicates an actual rainfall amount in the target area higher than computed through the use of the control station precipitation amounts. It should be noted that the 1950 data fell to the right of the regression line on six of the seven charts. For any particular rainfall value computed from the control station amounts the rainfall amount indicated by the regression line should be considered as the best estimate of the rainfall which would have occurred in the target area. The term "best estimate" is here used in the sense that approximately a 50-percent chance exists that the rainfall in the target area would have been less than indicated by the regression line and a 50-percent chance that more rainfall might have occurred than indicated. Consequently, the extent of the deviation of the 1950 data to the right of the regression line is to be considered as a probable increase due to cloud seeding with the understanding that there remains approximately a 50-percent chance that the deviation due to seeding might be more than the indicated value and roughly a 50-percent chance of the deviation being less than indicated.

Since figure 6 shows a unique position for the 1950 datum to the left of the regression line, some attention has been given to the month of November 1950 in the Pacific Northwest. It has been noted that the usual analysis method applied to the precipitation data from November 1–9, 1950, yields results comparable to those shown in the remaining six charts. As a consequence it appears that the storminess during the latter portion of the month was unusual to the extent that seeding effects comparable to those experienced in other months were not noted. Further study is being undertaken to determine the effects of seeding during the latter portion of November.

Figures 1 to 7 are not intended to offer proof of the effects of seeding on monthly rainfall totals. However, the fact that 1950 data during 6 of the 7 months fell to the right of the regression line is suggestive of important modifications in the monthly precipitation patterns. In addition, pending further analysis, the extent of the deviation to the right of the regression line may be taken as a measure of the possible increase in rainfall due to cloud seeding during the month.

It should be noted that, percentagewise, any rainfall increases shown in figures 1 to 7 do not appear to be a function of the average rainfall occurring in the area. There appears to be no important distinction between the percentage increase of rainfall possible in a dry month and in a wet month.

A logical analysis of figures 1 to 7 would appear to be an investigation of the statistical significance of the 1950 data as compared to the occurrences of past years. The problem is complicated considerably by the nonnormal distributions of monthly rainfall amounts and by the dependence of the deviations from the regression line (in terms of both inches and percentages) on the actual rainfall amounts. Considerable time has been devoted to this problem and it has not been considered desirable to include a discussion of the statistical significance until such time as adequate parameters can be developed which are less dependent on rainfall amounts.

During the winter of 1950–51 sustained cloud-seeding experiments were undertaken in the Colorado Rockies in an attempt to supplement the snowpack in the upper watersheds of the Arkansas, South Platte, and Rio Grande Rivers. Data available for preliminary analysis are principally snowpack values since complete climatological data are not yet published.

Figure 8 shows the percent of normal snowpack as of March 1, 1951, as published by the Soil Conservation Service. Dashed lines indicate the seeding areas. In the watershed of the upper Arkansas River (central Colorado) seeding was commenced during November and continued at every favorable opportunity throughout the winter. Areas to the north and south of the Arkansas watershed were seeded from late January or early February 1951, throughout the balance of the winter and consequently did not receive the benefit of a full winter's trials. Figure 8 shows the highest percent of normal (over 200 percent) snowpack in the area of the upper Arkansas River where seeding experiments were conducted during the entire winter.

In an attempt to formulate a statistical evaluation of this occurrence, correlations were computed between total precipitation amounts during the months of November through February at various stations on the western slopes of the Continental Divide and the average water content of the snowpack in the upper Arkansas watershed. Highest of these correlations (0.89) involved the relation between Aspen, Colo., precipitation and the upper Arkansas water content.

Table II shows the ratios of Aspen precipitation to Arkansas water content for the past years of record.

TABLE II.—*Ratios of Aspen precipitation to water content of Arkansas snowpack*

1940	0.83	1947	0.86
1941	.63	1948	.72
1942	.67	1949	.71
1943	.92	1950	.71
1944	.64		
1945	.72	Mean	.73
1946	.66	1951	.66

It is seen that the ratio of 0.66 observed in 1951 was the third lowest recorded during the past 12 years, a low ratio signifying a relatively heavy snowpack compared to Aspen precipitation amounts.

In addition to suggestions of rainfall increases which have been mentioned in the preceding paragraphs there have been certain visual and analytical indications that seeding as conducted during the experiments previously mentioned may distribute rainfall more uniformly over wide areas than is usually the case under natural conditions. Table III presents a suggestion of this effect.

In table III total rainy days per month in various ranges have been summed for the entire eight stations in the target area and four stations in the control area for all past Septembers. Since the number of rainy days is a direct function of the rainfall occurring in the area, 1950 has been compared to an average of past years having comparable rainfall amounts. Also included is a tabulation of the percentage change in total rainy days in 1950 compared to the average of past years with comparable rainfall amounts.

TABLE III.—*Total rainy days, September, southeast Colorado*

	Rainfall amounts				Average rainfall
	Trace to 0.09	0.10 to 0.29	0.30 to 0.69	0.70 or more	
Target area:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
(1) 30-year average	17.7	7.8	6.3	3.7	1.19
(2) Average wettest 40 percent of years	20.4	9.9	11.1	6.6	2.12
(3) 1950	40.0	19.0	18.0	5.0	2.11
Percent change (3) compared to (2)	+96	+92	+62	−24	0
Control area:					
(1) 21-year average	12.9	7.0	3.1	1.2	1.10
(2) 1950	13.0	13.0	3.0	0	1.06
Percent change (2) compared to (1)	0	+85	−3		−4

83116—51——22

Sizable percentage increases are shown in the target area for rainfall ranges below 0.70 inch with a comparable increase noted in the control area only in the 0.10–0.29-inch range.

There have also been numerous independent visual reports from the seeded areas indicating that rainfall during seeding periods has been more evenly distributed and gentler than has been customary in past years. If further data substantiate these indications it is believed that this modification of rainfall patterns will be fully as significant as possible increases in rainfall totals. Any such effects which may occur as the result of seeding are attributed to the impregnation of a broad air-stream with silver iodide crystals in contrast to local seeding of individual clouds.

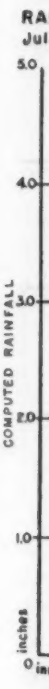
Although this report has dealt primarily with cumulative effects of seeding on monthly rainfall totals, it may be of some interest to include the analysis of an individual storm. Figure 9 shows the percentages of January normal precipitation which occurred as the storm of January 10–13, 1951, moved through the western half of the country. Although precipitation occurred on only one or two days at most locations, all rainfall values have been plotted on the same chart for visual comparison. As the storm passed through the western portion of the country seeding was conducted by the Water Resources Development Corp. in portions of southern California, southeast Arizona and southeastern Colorado. These seeding areas coincide with the shaded areas in figure 9 which represent the occurrence of 50 percent or more of the normal January precipitation amounts. It is reliably reported that seeding was also conducted in the San Joaquin Valley of California in approximately the region when the remaining important area of 50 percent or more of normal monthly precipitation is indicated. It should be noted that prevailing meteorological conditions became favorable for cloud seeding in all indicated areas as the storm passed through the western portion of the country. It is doubtful if such favorable conditions would often be repeated. However, the distinct rainfall pattern produced is unusually striking when consideration is given to the areas being seeded during the storm.

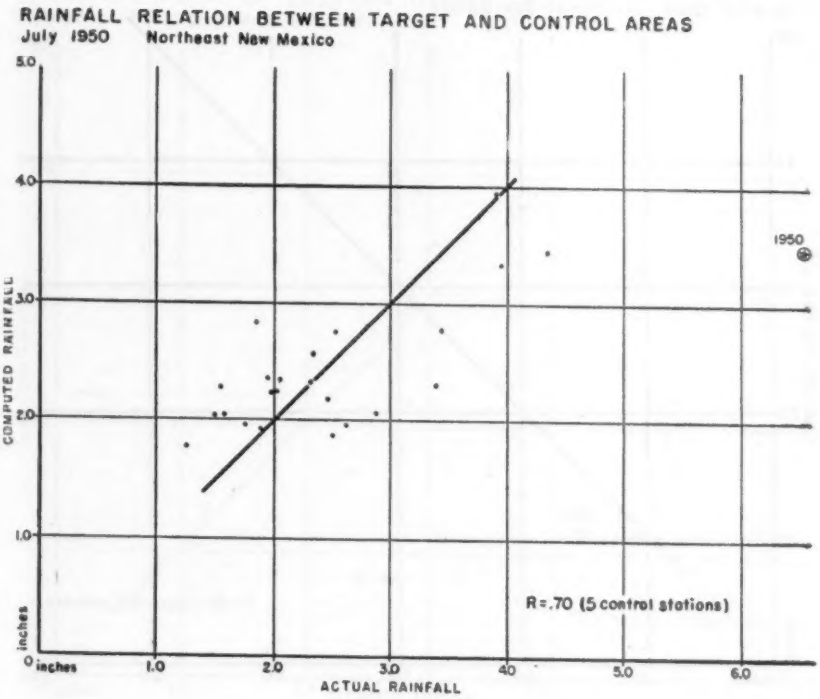
An attempt has been made to investigate an unseeded storm during past years with a similar path and similar characteristics. Figure 10 shows the rainfall pattern produced by the storm of December 31, 1931, to January 5, 1932. The principal difference between the storms shown in figures 9 and 10 is the more northerly path of the 1951 storm through New Mexico. As shown in figure 10, largest percentages of normal occurred to the east of the Rocky Mountain States. Apparently this feature of the pattern is characteristic of such storms and accounts in part for the larger percentages of normal in southeast Colorado during the 1951 storm compared to other seeded areas. From New Mexico westward the rainfall patterns shown in figures 9 and 10 are markedly different.

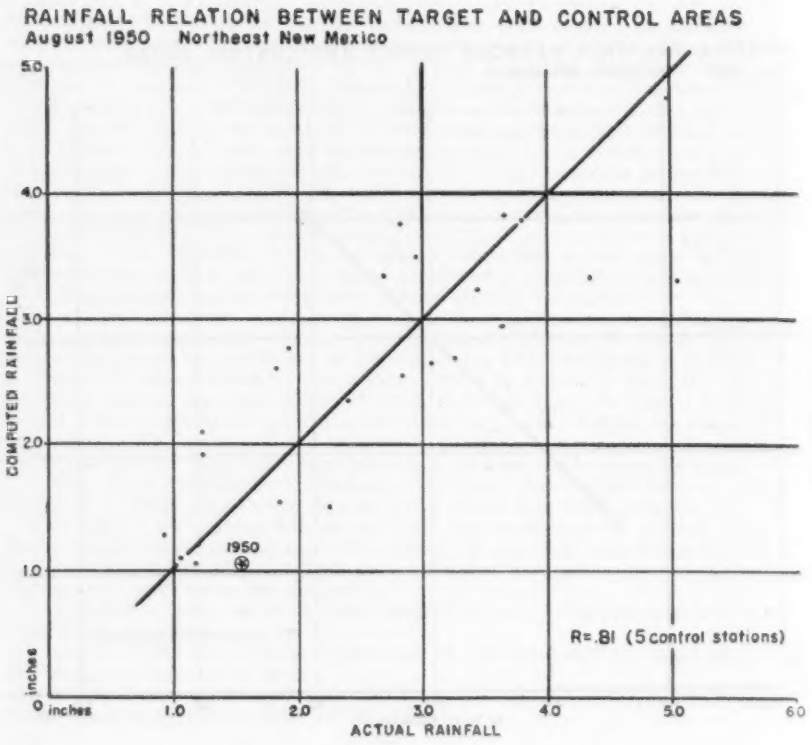
This report has attempted to indicate the possibility of certain significant modifications in rainfall patterns as a result of sustained cloud seeding. If further data substantiate the indications mentioned previously, two important conclusions will have been demonstrated:

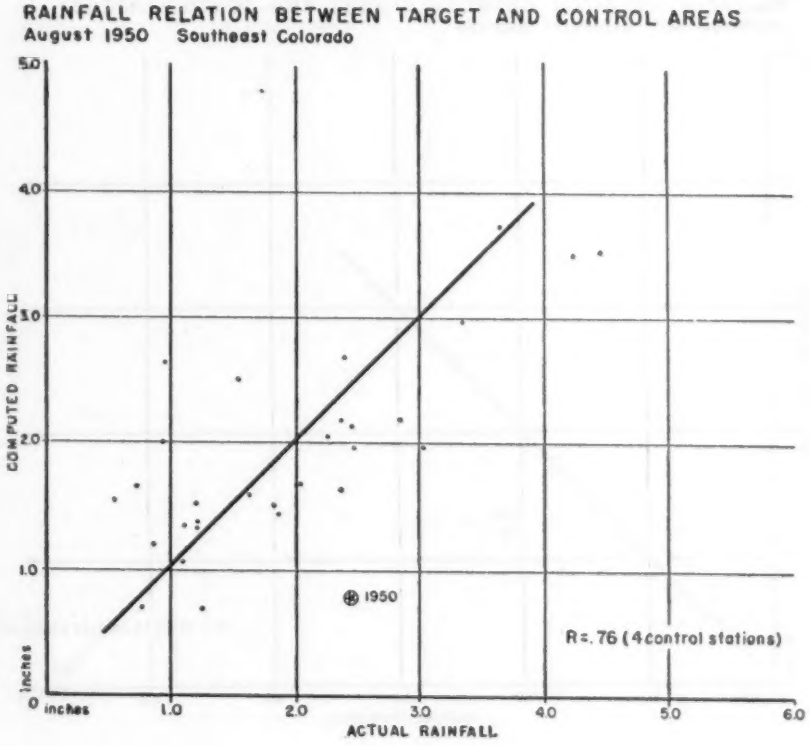
1. Significant increases in monthly rainfall totals can be achieved by sustained cloud-seeding activities.
2. Operation of the seeding equipment can be regulated to target the rainfall increases over a localized area.

It is hoped that additional data will become available in the future for further analyses along similar or more refined lines.

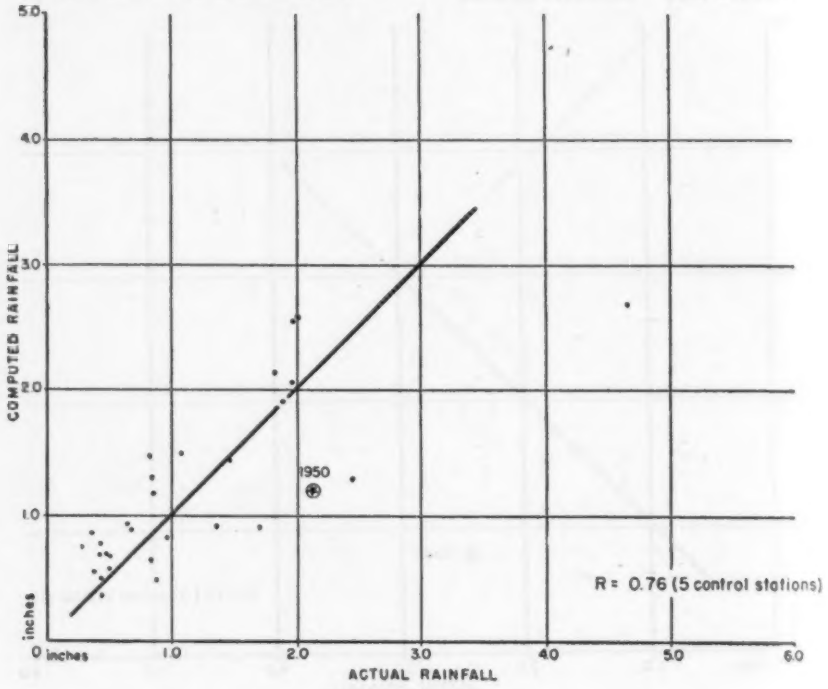


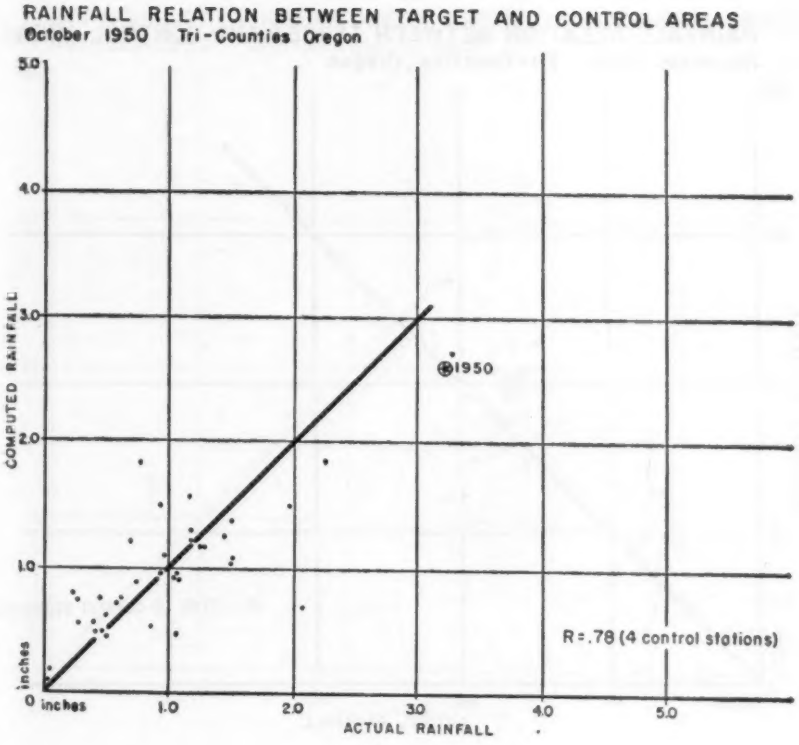

RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
July 1950 Northeast New Mexico
5.0
4.0
3.0
2.0
1.0
0 inches
COMPUTED RAINFALL
1950
R=.70 (5 control stations)
1.0
2.0
3.0
4.0
5.0
6.0
ACTUAL RAINFALL

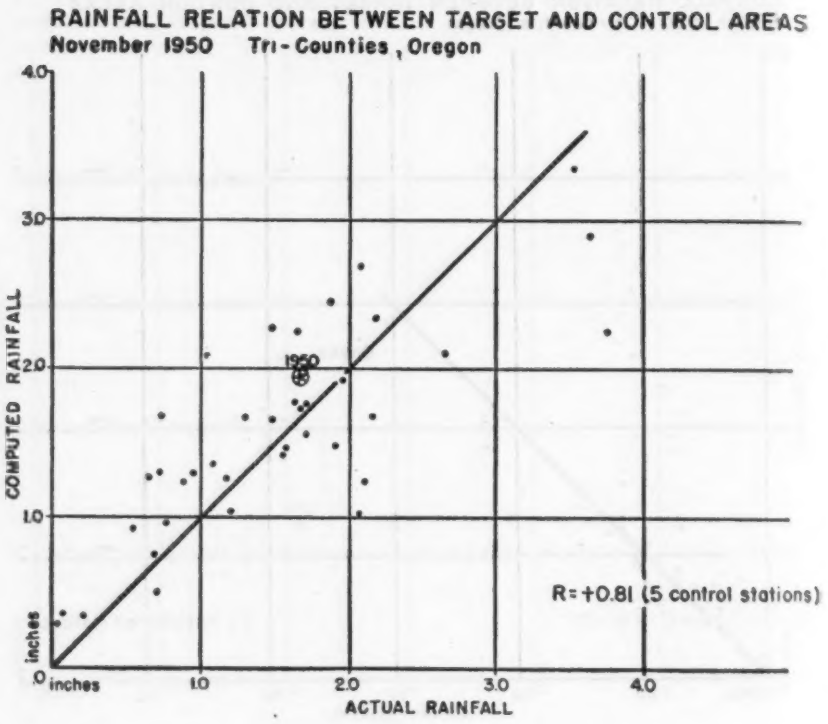

RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
August 1950 Northeast New Mexico
COMPUTED RAINFALL
5.0
4.0
3.0
2.0
1.0
inches
0 inches
1.0
2.0
3.0
4.0
5.0
60
ACTUAL RAINFALL
1950
R=.81 (5 control stations)

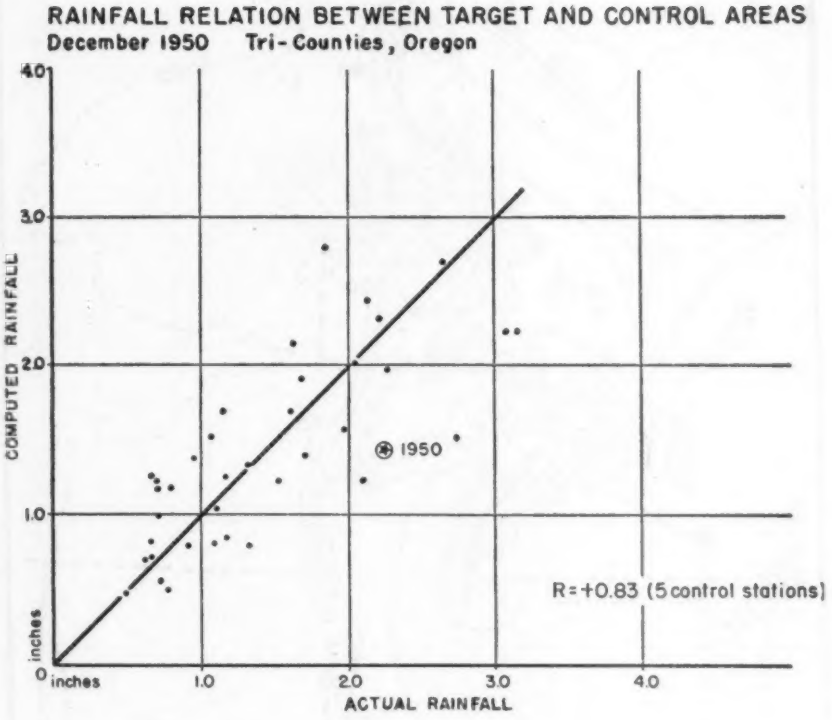

RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
August 1950 Southeast Colorado
COMPUTED RAINFALL
inches
5.0
4.0
3.0
2.0
1.0
0
inches
1.0
2.0
3.0
4.0
5.0
6.0
ACTUAL RAINFALL
⊕ 1950
R=.76 (4 control stations)

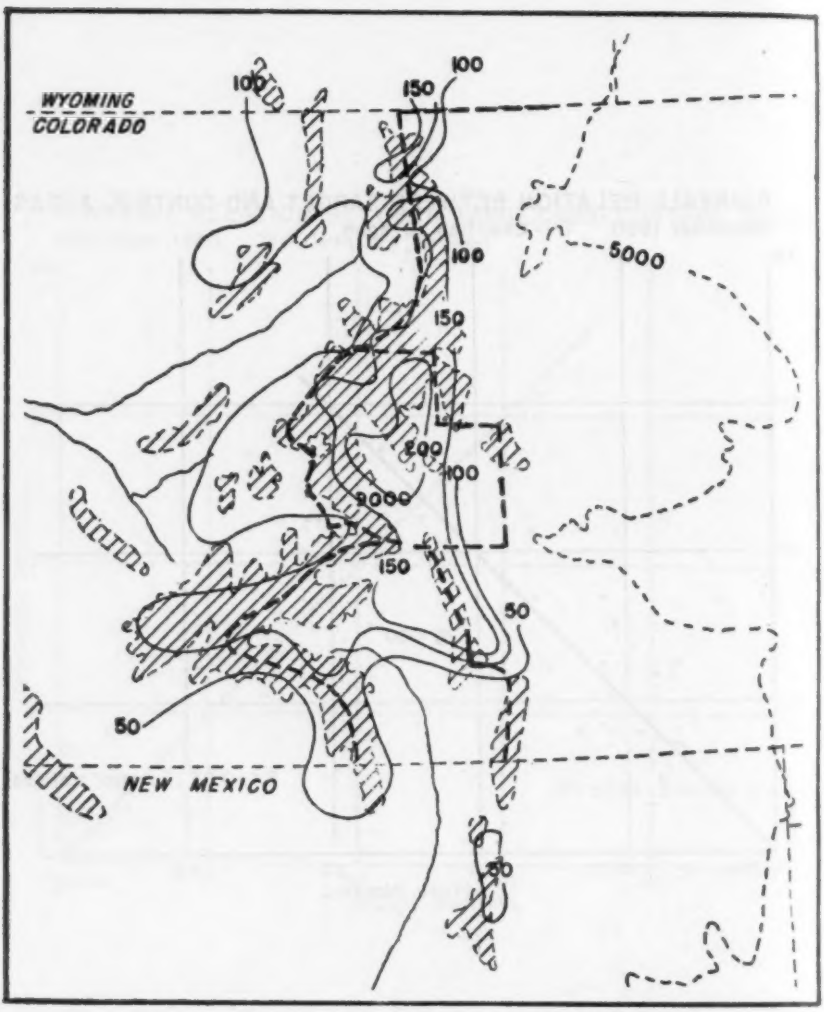
RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
September 1950 Southeast Colorado



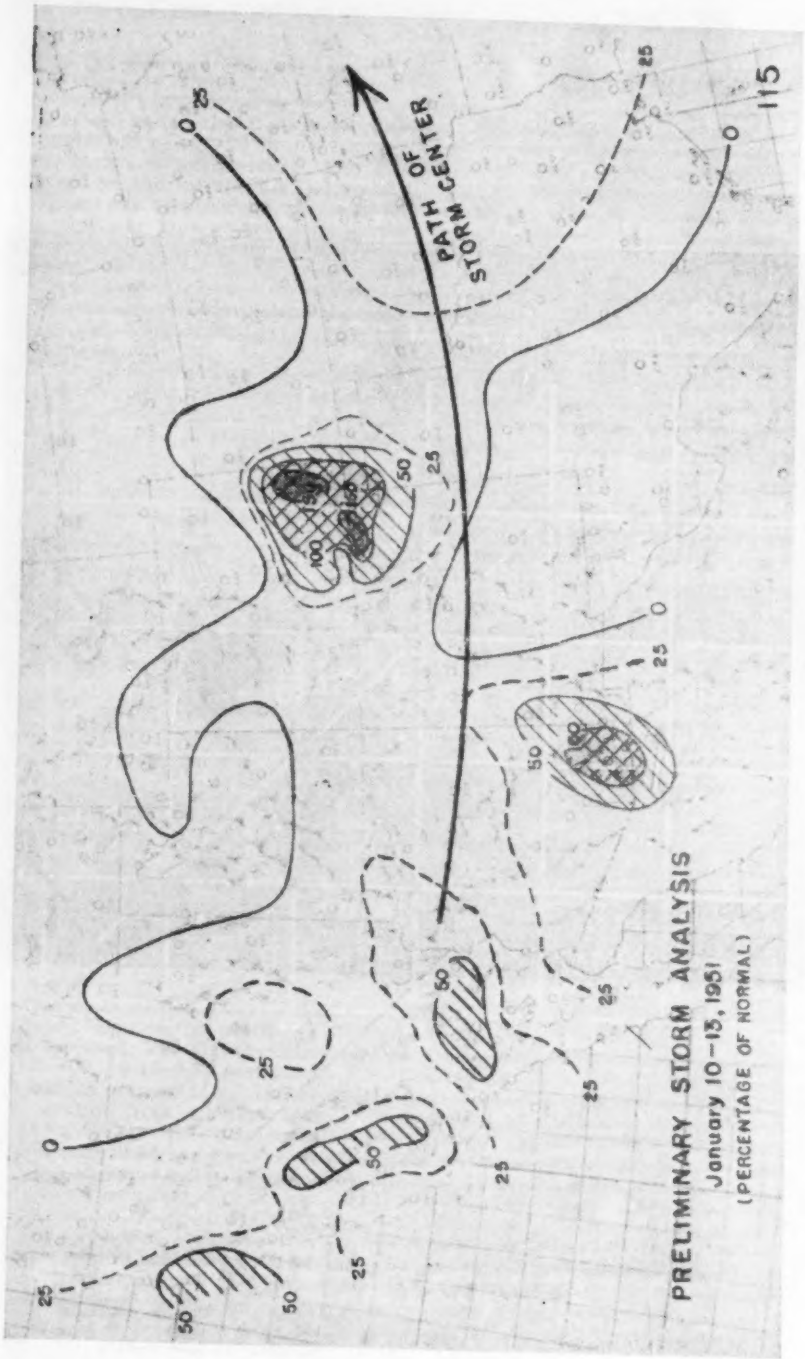

RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
October 1950 Tri-Counties Oregon
COMPUTED RAINFALL
inches
0
1.0
2.0
3.0
4.0
5.0
1950
R=.78 (4 control stations)
ACTUAL RAINFALL

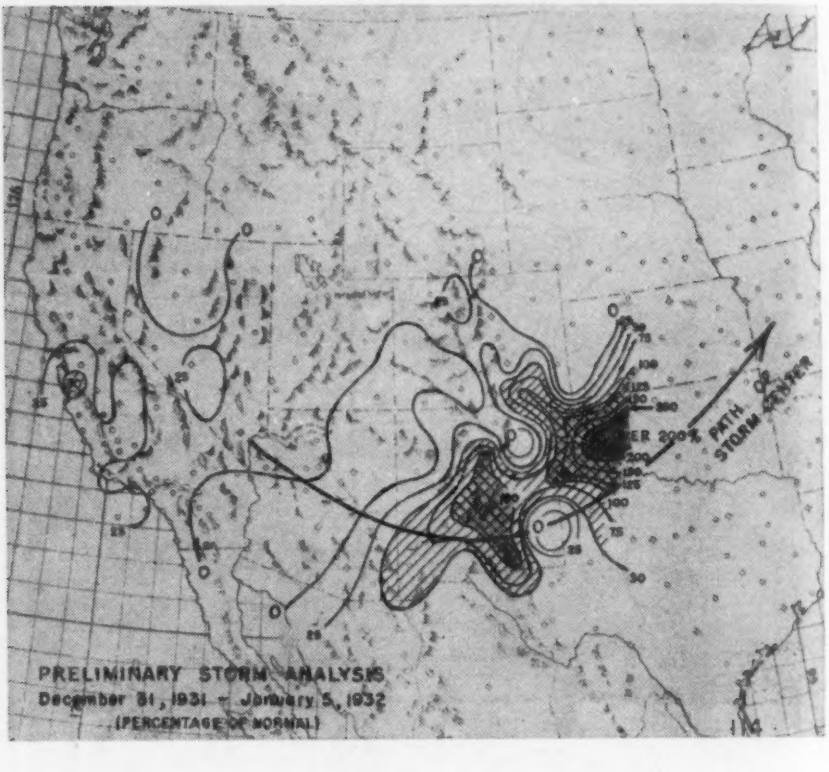

RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
November 1950 Tri-Counties, Oregon
COMPUTED RAINFALL
ACTUAL RAINFALL
4.0
3.0
2.0
1.0
0 inches
1950
R=+0.81 (5 control stations)


RAINFALL RELATION BETWEEN TARGET AND CONTROL AREAS
December 1950 Tri-Counties, Oregon
COMPUTED RAINFALL
inches
4.0
3.0
2.0
1.0
0
inches
1.0
2.0
3.0
4.0
ACTUAL RAINFALL
1950
R=+0.83 (5 control stations)



PERCENT OF NORMAL SNOW PACK
Mar. 1, 1951


PATH OF STORM CENTER
115
PRELIMINARY STORM ANALYSIS
January 10–15, 1951
(PERCENTAGE OF NORMAL)


PRELIMINARY STORM ANALYSIS
December 31, 1931 - January 5, 1932
(PERCENTAGE OF NORMAL)
PATH OF STORM CENTER

The Phase Diagram of Sodium Chloride and Steam Above the Critical Point

(Arne Ölander and Halvard Liander, Institute of Inorganic and Physical Chemistry, University of Stockholm, and ASEA, Västerås, Sweden,

It is well known that high-pressure steam dissolves several solids, such as sodium chloride, silica, etc. This has caused great trouble in power plants operating with higher steam pressure than 75 kg/cm,[2] as the dissolved substances will deposit on the turbine blades, heavily impairing their efficiency. Our original purpose was to ascertain the solubility of sodium chloride in steam at higher temperatures and pressures than were previously measured, but we have also studied the displacement of the critical phenomena, when salt is added to the water.

An extensive review of the work hitherto carried out in this field has recently been published by Booth and Bidwell,[1] so it will be sufficient for us to direct the attention of the reader to the work of Spillner[2] and of Straub,[3] both of whom investigated the salt contents of the steam phase by its electrical conductivity after cooling. Spillner also measured the dielectric constant of steam. He found that the conductivity of the solution of salt in steam was very small, so the

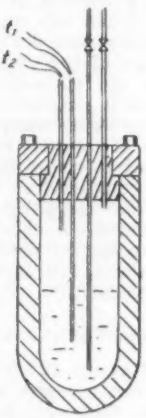


Fig. 1.—High-pressure vessel

electrolytic dissociation must be negligible, as could be expected from the low dielectric constant, the latter being only about 2.9 at the critical point. Schröer[4] measured the raising of the critical temperature when various halides were added to the water.

EXPERIMENTAL

Our measurements were carried out in a steel bomb, Fig. 1, which was lined with copper, about 5 mm thick. The steel was delivered by Wikmanshyttan. The quality used, VH 312, should, according to Swedish standards, contain 0.23–0.28 percent C, 0.15–0.35 percent Si, 0.50–0.80 percent Mn, 0.9–1.2 percent Cr and 0.15–0.25 percent Mo. Its tensile strength was ca. 72 kg/mm² at 500° C (communication from the steel work). The volume of the bomb was a little more than 5 litres. The bomb was heated by an electrical winding and was insulated with kieselguhr. The temperature was measured to 1° C with chromel-alumel-thermocouples, calibrated at the melting points of Sn, Pb, and Zn. Two couples were situated in borings in the upper and lower part of the bomb and two were inside tubes running through the cover of the bomb and ending at different heights inside it. Usually the four thermocouples differed by only 1° C or less. The pressure was read to 1 kg/cm² on a Bourdon manometer calibrated by The Government Testing Institute, Stockholm, twice during the course of the investigation.

[1] Booth, H. S., and Bidwell, R. M. *Chem. Rev.* 44 (1949, 3.
[2] Spillner, F. *Chem. Fabrik* 13 (1940), 405.
[3] Straub, F. G. *Univ. Ill. Bull.* 43 (1946), 59.
[4] Schröer, E. Z. *phys. Ch.* 129 (1927), 79.

Samples were let out from the bomb through copper capillaries with 1 mm inner diameter, one ending near the top, the other near the bottom of the bomb. The capillaries passed through cooling mantles before the liquid was discharged through steel valves. Before a sample was taken for analysis an adequate quantity was let out through the capillary and discarded, in order to ensure that the sample gave the true composition of the phase in which the capillary ended. The chloride ion was titrated with silver nitrate using chromate as an indicator. The concentrations are given in weight per cent. The density of the high temperature phases was not measured, so the concentration in them cannot be given.

The bomb was filled through a steel pump. Both this and the steel valves rusted of course, but the iron hydroxide formed does not affect the measurements. The copper lining was also somewhat attacked, and especially the samples from the bottom of the bomb were usually more or less turbid from some cuprous chloride and oxide. Presumably these compounds precipitated during the cooling of the sample and were kept in solution as complex compounds in the hot interior of the bomb. Their amount was so small that they cannot possible have interferred with the measurements. Of course, there are much better materials than copper, but the vessel was available from an earlier investigation of technical nature concerning the possibility of making potable water from sea water by distillation at high pressure.[5]

After the bomb was filled with a solution, it was heated, during which procedure liquid had to be let out. When the required temperature was reached and equilibrium established, samples were let out through the two capillaries, ending in the upper and lower part of the vessel. At the beginning these had the same composition, but below a certain pressure the contents parted into two phases, one at the bottom, being richer in salt, and another at the top with less salt. Near this critical pressure samples were taken at every kg/cm^2. Between the taking of every pair of samples at least 30 minutes were allowed to pass, often much more, in order to reestablish temperature equilibrium and allow the two phases to separate completely. With sinking pressure the lower phase became richer in salt, but the sampling had to be interrupted when its salt content exceeded 26 percent which is the solubility at room temperature, to avoid the capillary being obstructed by precipitated salt. The upper phase was sampled down to pressures about 150 kg/cm^2, where its salt content was of the order of magnitude 0.005 percent.

MEASUREMENTS

Runs were made at intervals of about 10° from 353° C. to 475° C. At temperatures higher than 445°, however, samples were taken only from the upper phase. In most cases two or three runs were carried out at every temperature. Samples were taken at every kg/cm^2 near the pressure at which the separation into two phases occurred, then at every 5 kg/cm^2, but at those pressures where only the upper phase was investigated at every 10 kg/cm^2. For every temperature the salt contents were plotted against the pressure and a smoothed curve drawn. Some of these are given in Fig. 2. At temperatures higher than 374° C., the critical temperature of pure water, the curves for the two phases will meet at a critical point, which corresponds to the highest pressure under which two phases can exist at that temperature.

In order to obtain this critical turning-point to the right of each curve one has to choose a definite critical composition of the solution, which is richer in salt the higher the temperature is. If a different composition is used, the formation of two phases will occur at a lower pressure and the middle part of the curve is lost. The critical composition is obtained if the mean value of the compositions of the two phases is also plotted in the diagram. This gives a slightly bent curve which is extended to the critical pressure at that temperature. This pressure could be ascertained to within ± 1 kg/cm^2, as the pressure of separation was changed only a little if the original composition was not too far from the critical one. After a few preliminary experiments it was then possible to choose the correct solution for each temperature.

The logarithms of the salt contents of the upper phase, mostly less than 1 percent were also plotted again the pressure, whereby rather straight lines were obtained, Fig. 3. When all the results were plotted it was seen that the mean deviation of the measured points from the mean curves was about ± 2 kg/cm^2. Our measurements agree well with Spillner's few measurements at 407° C.[2].

[2] Spillner, F., *Chem. Fabrik* 13 (1940), 405.
[5] von Platen, B., *U. S. Pat.* 2,520,185 (1950).

If the compositions of the phases are plotted against the temperature, we get, for each constant pressure, a curve showing the temperature *above* which two phases will occur.

At temperatures lower than 374° C. the curves in Fig. 2 will start at zero salt concentration and the vapour pressure of pure water, as is shown for 363° C.

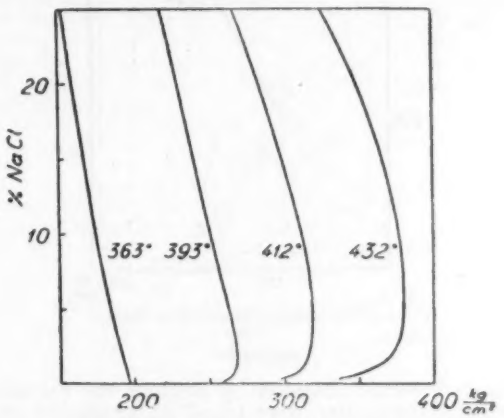


FIG. 2.—Salt content of liquid, $p-c$-diagram

This curve gives the vapour pressure of solutions up to 25 percent NaCl. The steam above these solutions also contains some sodium chloride, but the amount is so small that it cannot be shown in the same figure. Fig. 4 gives the salt concentrations at two temperatures. These results are much less accurate than the other measurements. Sometimes greater concentrations were found which

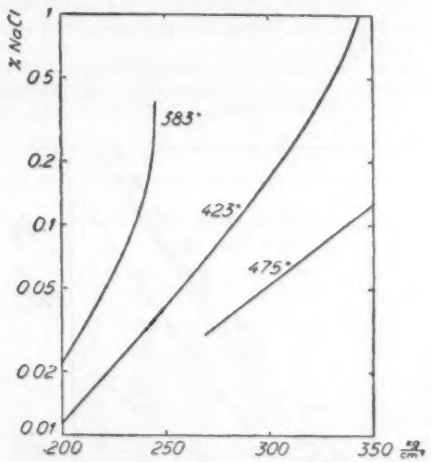


FIG. 3.—Salt content of steam, $p-c$-diagram

is believed to be due to drops of the liquid solution being dragged along with the steam. The dashed parts of the curves are extrapolated.

Spillner [2] found that the steam containing salt had no electrical conductivity so there are no ions in it, but NaCl-molecules. He also measured the di-electric constant at the critical point to be 2.9, so that this water should be regarded as a "nonaqueous solvent."

[2] Spillner, F., *Chem. Fabrik* 13 (1940), 405.

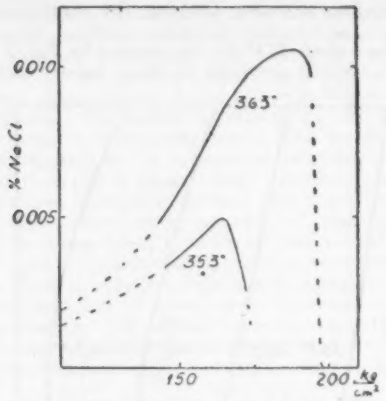


FIG. 4.—Salt content of steam, p—c-diagram

RESULTS

From the smoothed curves obtained by plotting the concentration against pressure the critical compositions were found as mentioned above and these values plotted against temperature and pressure. A smoothed curve was drawn again, from which the plotted points only deviated by 0.1 percent. The smoothed values are:

TABLE 1.—*Critical curve for NaCl-solutions*

Percent NaCl	0	0.2	0.5	1.0	1.5	2.0	3	4	5	6	7
t° C	374	379.5	383.5	388.5	394	399	408.5	416.5	424	431	437.5
p kg/cm²	224	239	248	259	271	283	309	332	354	376	397

If the values of the last two lines are plotted in a p-t-diagram a curve is obtained which forms a continuation of the vapour pressure curve of pure water, the uppermost curves in Figs. 5 and 6.

In this p-t-diagram were also plotted the smoothed pressure values corresponding to different concentrations, for all temperatures investigated. The resulting curves for the lower, concentrated phase are given in Fig. 5, and for the upper

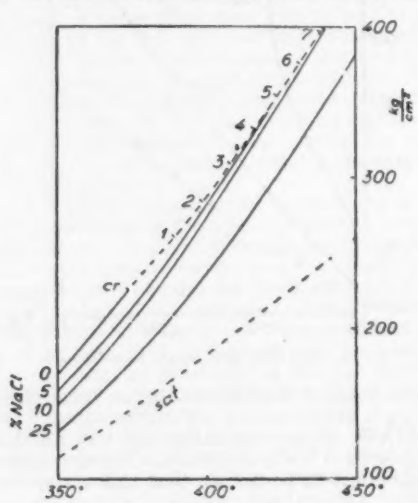


FIG. 5.—Salt content of liquid, t—p-diagram

steam phase in Fig. 6. The values, once more smoothed, are contained in Table 2. The broken line crossing the table indicates the place of the critical states, the pressures of which are given in the second line. The numbers above the broken line refer to steam hotter than 374° C., those below it to the phase at the bottom of the vessel.

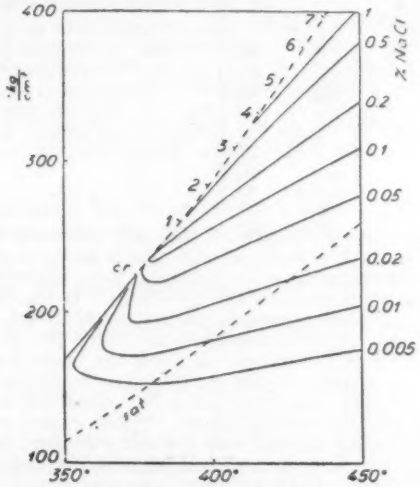


FIG. 6.—Salt content of steam, t—p-diagram

In one experiment steam was let out from the vessel until the solution was saturated. This was indicated by the fact that, after letting out more steam, and raising the temperature to its original value before the letting out, the former pressure was restored. It was also found that the capillary outlet from the bottom was choked by salt, so it was difficult to pump more solution into the vessel. The pressures of the saturated solutions are given in the last line of Table 2 and the corresponding curve drawn in Figs. 5 and 6.

In the experiments in which the pressure became less than that of the saturated solution, the lower phase could not more be liquid, but was solid sodium chloride. Regarded as a phase diagram, Figs. 5 and 6 show three areas: at the left top a one-phase area, in the middle an area of two phases, liquid and steam, and at the right bottom the area of solid salt and superheated steam.

TABLE 2.—*Pressure at which a phase exists containing the amount of salt shown in the first column*

t=	350	360	370	380	390	400	410	420	430	440	450	460	475° C.
Crit. Pr.				240	262	286	313	343	373	405	436		
0%	169	191	215										
0.005%				149	154	159	163	166	169	171			
0.01				172	178	184	190	194	198	202	205	208	
0.02				193	199	206	213	220	226	231	236	241	
0.03				206	211	218	227	234	241	248	254	259	267
0.05				220	226	234	243	252	261	269	277	285	296
0.1				234	242	253	264	275	286	297	308	318	334
0.2				240	254	268	233	297	311	325	338	352	372
0.5	167	189	213	240	260	280	301	321	341	361	379	396	
1.0	166	187	211	236	262	284	309	333	358	382			
2.0	163	184	208	234	262	286	313	340	368	396			
5.0	157	178	201	226	254	283	313	343	373	403			
10	148	169	192	216	244	284	305	338	371	405			
15	140	161	184	208	233	261	291	324	369	395			
20	133	154	176	199	222	248	277	309	341	376			
25	127	147	168	189	211	235	260	289	321	256			
sat.	113	127	141	155	169	183	198	213	227	243	258	273	297

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TABLE 3.—*Approximate salt content of steam below the critical point of pure water (in parts per million)*

p kg./cm.²	353°	363°	372°
140	30		
150	37		
160	46	77	
165	50		
170	35	93	105
175	0		
180		101	140
190		106	180
195		90	
198		0	
200			200
205			260
210			100
211			88
220			0

TABLE 4.—*Salt content of solutions in equilibrium with the steams recorded in table 3 (in percent)*

353°	363°	372° C.
21.8		
13.5	26	
7.0	18.8	
4.3	15.4	
1.9	12.3	27
0	9.2	24
	7.0	20.7
	2.9	14.3
	1.0	11.4
	0	9.7
		8.5
		5.9
		3.4
		3.0
		0

Table 3 gives approximate values of the salt contents of steam at three temperatures below the critical point of pure water in *parts per million*. Table 4 gives in *percent* the salt contents of the solutions in equilibrium with the steams in Table 3 at the same temperatures and pressures. If the compositions of the two coexisting phases at some temperature above 374° are wanted, they can easily be obtained if the composition-pressure curve for that temperature is drawn, when they are found as the two values of the curve for a given pressure.

These results give an answer to the problem as to whether it is possible to free the steam from a boiler from the salt it has dissolved which is of interest in steam engineering (cf. the introduction). Spillner and others [2] are of the opinion that it is not possible to wash out the salt with feed water, but Straub [3] succeeded in purifying the steam to a high degree by running the steam through a small fractionating column with four bubble cap plates, and even with a column with only one single plate. If a phase diagram (c—t-diagram) is constructed from the measurements in this investigation, it will be seen, that the steam with salt (*cf.* Tables 3 and 4, *e. g.* at 170 kg/cm²) will be in equilibrium with a water very much more rich in salt. Our results thus support Straub's, and it should be possible to wash the steam free from salt in a scrubber, provided the pressure is lower than 224 kg/cm², the critical pressure for pure water.

The results show that a salt solution at 300 kg/cm and 475° C yields a steam with a little more than 0.05 percent NaCl and a liquid which is almost saturated at room temperature. The advantage of this distillation procedure according to an invention by Baltzar von Platen is that the thermal efficiency is much better at this pressure and temperature than at atmospheric pressure.[5] Mr. von Platen considers that water with 0.05 percent NaCl, obtained from sea water, could be used for drinking and irrigation in places where potable water is scarce. A further purification by means of ion exchanger would be rather cheap. Such water could be immediately used as boiler water as the solubility of calcium and magnesium ions in the steam is very small. We have distilled sea water from Skagerrak at the west coast of Sweden with a chlorosity [6] of 14.72 g Cl−/lit. at 300 kg/cm² and 450° C. The distillate contained 0.62 g/lit. Cl−, $2.9 \cdot 10^{-4}$ mol/lit. $Ca2+ + M_g 2+$ (mean values from two experiments) and no sulphate ion detectable with barium salt.

SUMMARY

The phase diagram of the system sodium chloride—water—steam has been investigated in the region 353°—475° C. and 150—400 kg/cm². Values are given for the vapour pressures of solutions and the solubilities of sodium chloride in steam.

A new method of making potable water from sea water is mentioned.

The apparatus was attended by Mr. Fritz Wallin and Mr. Gustav Eriksson. The analyses were carried out by Mr. Ane Swärdh. During the last part of the investigation Baron Casper Wrede, Mr. Hans Dinger and Mr. Erik Lundblad also took part in the work.

[2] Spillner, F., *Chem. Fabrik* 13 (1940), 405.
[3] Straub, F. G., *Univ. Ill. Publ.* 43 (1946), 59.
[5] von Platen, B., *U. S. Pat.* 2,520,186 (1950).
[6] Sverdrup, H. U., Johnson, M. W. and Fleming, R. H. *The Oceans*, Prentice-Hall Inc., New York, 1946, p. 52.

DEPARTMENT OF THE INTERIOR,
BUREAU OF RECLAMATION,
Washington, D. C., May 25, 1951.

Hon. JOSEPH C. O'MAHONEY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

MY DEAR SENATOR O'MAHONEY: In connection with the hearings on S. 5, S. 222, and S. 798, concerning salt-water conversion and artificial precipitation, we are pleased to furnish you with copies of State legislation in the field of artificial precipitation, which to date have come to our attention. The enclosed copies of acts and bills do not purport to represent all of the legislation proposed and enacted in the field of artificial precipitation by the 17 Western States.

The proposed and enacted legislation by each State is as follows:

Oregon

House Joint Resolution No. 22, enacted in the last legislative session.

House bill No. 666, not acted upon by the House.

Wyoming

Enrolled Act No. 53, dated February 19, 1951, enacted in the last legislative session.

(The Wyoming act referred to was inserted earlier in the hearing. See p. 166.)

Colorado

H. B. No. 251, enacted in the last legislative session.

California

A. B. 2706, A. B. 101, S. B. 388, S. B. 617, and S. B. 986 which were not acted upon by either House of the Legislature.

Arizona

Although a copy has not been made available to us, it is understood that there is a recently enacted statute on this subject.

Nevada

It is also understood, although a copy has not been made available to us, that a bill on this subject was introduced in the last session of the State legislature.

New Mexico

We are informed, without having seen copies thereof, that there is either recent or pending legislation on this subject.

(The New Mexico law was subsequently supplied.)

As we receive further legislative documents and information concerning this subject matter, we will advise you.

Sincerely yours,

G. W. LINEWEAVER,
Acting Commissioner.

[Forty-sixth Legislative Assembly, State of Oregon—Enacted, Regular Session. House Joint Resolution No. 22]

Whereas significant progress in the science of weather control and modification make it probable that widespread attempts will be made in the near future to utilize knowledge gained from study of the science of weather modification and control to change or alter natural weather conditions; and

Whereas notwithstanding progress made in this field, the effect of the use of measures for the control of weather phenomena upon the social, economic, and political structures of the State and Nation cannot be determined; and

Whereas the courts may become clogged with litigation if measures taken to control or modify natural weather conditions produce adverse results of any nature; and

Whereas the Legislature of the State of Oregon recognizes that any measures taken to control or modify the weather are of concern of every resident of the State; and

Whereas the Legislature of the State of Oregon deems it necessary that a thorough study of the problems relating to weather control and modification be made before legislation is enacted: Now, therefore, be it

Resolved by the House of Representatives of the State of Oregon, the Senate jointly concurring: That there hereby is created an interim committee of the Legislative

Assembly, to consist of seven members, two or whom shall be appointed by the President of the Senate from members of the Senate, three of whom shall be appointed by the Speaker of the House of Representatives from the members of the House of Representatives and two of whom shall be appointed by the Governor. The committee shall choose one of its members as chairman; be it further

Resolved, That it shall be the duty of the committee to conduct investigation and research into the scientific, industrial, and legal developments and advances made in the field of weather control and modification, and to this end it is authorized to cooperate with any scientific, State, or Federal agency which has as its purpose the study and research into any aspect of weather control and modification; be it further

Resolved, That the committee hereby is empowered to hold public hearings, to make such investigations and surveys as it deems advisable, and to employ the services of a secretary, not a member of the committee, and such other technical and clerical help as it may deem necessary to assist in accomplishing the purposes and intent of this resolution and the committee shall fix the amount of compensation of its employees; be it further

Resolved, That it shall be the duty of the committee, after completing its work, to prepare for submission to the next regular Legislative Assembly a detailed compilation of the results of its investigation and research, together with its recommendations for legislative action thereon; and be it further

Resolved, That each member of said committee shall receive his actual and necessary expenses incurred in the accomplishment of the purposes for which appointed. The Secretary of State hereby is authorized and directed to audit and allow all such claims as shall be approved by the chairman of the committee and to draw his warrant on the State Treasurer for the payment thereof out of the appropriation for the payment of expenses of the Forty-sixth Legislative Assembly in the same manner as other expenses of the session are audited and paid, except the sum of such payments shall not exceed $5,000.00.

[Forty-sixth Legislative Assembly—Enacted, Regular Session. Senate Amendments to House Joint Resolution No. 22]

On page 1, line 22 of the printed resolution, delete the word "seven" and insert in lieu thereof the word "five".

On page 1, line 23 of the printed resolution, preceding the word "three" delete the comma and insert in lieu thereof the word "and."

On page 2, line 1 of the printed resolution, after the word "Representatives" insert a period and delete the remainder of the line.

On page 2, line 2 of the printed resolution, delete the words "appointed by the Governor." and insert in lieu thereof the following: "The committee shall meet and consult with two advisory members to be appointed by the Governor."

On page 2, line 22 of the printed resolution, after the word "each" and preceding the word "member" insert the words "legislator and advisory."

[Forty-sixth Legislative Assembly, State of Oregon—Not Enacted, Regular Session. House Bill No. 666]

A BILL For an Act relating to weather control and modification

Whereas significant progress in the science of weather control and modification make it probable that widespread attempts will be made in the near future to utilize knowledge gained from study of the science of weather modification and control to change or alter natural weather conditions; and

Whereas notwithstanding progress made in this field, the effect of the use of measures for the control of weather phenomena upon the social, economic, and political structures of the State and Nation cannot be determined; and

Whereas the field of weather control and modification is one in which there are still many unknown factors involved; and

Whereas the utlimate extent to which weather modification and control may be utilized is speculative, the application of measures to control weather without proper safeguards, sufficient data, and accurate information may result in catastrophic droughts, storms, floods and other phenomena with consequent loss of life and property, injury to water supplies for municipal, irrigation, and industrial purposes, injury to sources of hydroelectric power, and injury to production and transportation; and

Whereas the courts may become clogged with litigation if measures taken to control or modify natural weather conditions produce adverse results of any nature; and

Whereas the Legislature of the State of Oregon recognizes that any measures taken to control or modify the weather are of concern to every resident of the State; and

Whereas it is the intention of the Legislature of the State of Oregon that maximum benefit and minimum harm result from the application of weather control methods, now therefore,

Be It Enacted by the People of the State of Oregon:

SECTION 1. As used in this Act:

(1) "Weather modification and control" means initiating, changing, or controlling the course or effect of the forces, masses, and other factors constituting weather phenomena, including temperature, wind direction and velocity, and the inducing, increasing, decreasing, and preventing by artificial methods of precipitation in the form of rain, snow, hail, sleet, mist, or fog.

(2) "Commission" means the Oregon State Weather Control and Modification Commission.

(3) "Person" is any individual partnership, corporation, or association of individuals of whichever nature.

SEC. 2. There hereby is created the Oregon State Weather Control Commission whose functions and duties, in addition to those specified in other sections of this Act, shall be:

(1) Establish weather-control regulations necessary to protect life, property, and public interests within the State.

(2) When funds are available, to promote and foster programs of research and experimentation, by public and private institutions within the State, into the theory and development of methods of weather modification and control.

(3) Utilize, as far as practicable, present and future advances in the field of weather control and modification to initiate and conduct through the medium of State and private agencies programs of weather control and modification.

(4) Promulgate rules, regulations, and procedures for the issuance of licenses, by the State Engineer for persons who seek to make practical application of advances in the field of weather control and modification.

(5) Establish areas or zones within the State within which the activities of any person licensed under the provisions of this Act must confine his weather-control activities.

(6) Enter into any contracts or agreements necessary to carry out the provisions of this Act.

(7) Authorize expenditure by the State Engineer of any funds appropriated to it by the legislature, or from any other source to carry out the provisions of this Act.

(8) Hold public hearings at least twice a year, at times and places designated by the Commission, at which any interested person may be heard on any matter germane to weather control and modification.

(9) Meet with each advisory board at least once each year to receive their findings and recommendations.

(10) Require any person to submit his plans for any weather-control operation as a condition precedent to the issuance of a license.

(11) Represent the State of Oregon in any and all matters pertaining to plans, procedures, or negotiations for interstate compacts relating to weather control.

SEC. 3. The Commission shall consist of three members, who shall serve by virtue of their office, the Director of Agriculture, the State Engineer, and the State Forester.

SEC. 4. In addition there hereby are created two advisory boards which shall be known as the "Weather Control Legal Board" and the "Weather Control Research Board."

SEC. 5. (1) The Weather Control Legal Board shall consist of the Attorney General, and an Assistant Attorney General appointed by him and three members of the Oregon State Bar Association. This board shall conduct research into the legal aspects of weather control and report its findings and recommendations to the Commission twice each year.

(2) The "Weather Control Research Board" shall consist of eight members, including two scientists each from the faculties of Oregon State College and the University of Oregon and one member each from the agricultural, forestry, hydroelectric, and municipal interests of the State. This board shall conduct research

into the economic and scientific aspects of weather control and report its findings and recommendations to the Commission twice each year.

(3) As soon as practicable after the taking effect of this Act the Governor shall appoint to the membership of the advisory boards created by this section the person specified by paragraphs 2 and 3 of this section except those who served by virtue of their office.

(4) Two members of each board shall be appointed by the Governor for terms of one year and the remaining members of each board for terms of two years. Thereafter the Governor shall appoint each member or his duly appointed successor for a term of four years from the expiration of the term for which his predecessor was appointed, except that a person appointed to fill a vacancy occurring prior to the expiration of any term shall be appointed for the remainder of such term.

SEC. 6. The State Engineer shall administer and enforce the provisions of this Act and may employ such assistants as the Commission may from time to time recommend, if funds are appropriated for the purpose.

SEC. 7. (1) No person shall engage in weather modification and control activities, except under and in accord with a license issued by the State Engineer. The State Engineer shall issue licenses upon recommendation of the Commission only. However, no license shall be required for any agency, public or private, whose weather-control activities are a part of any research or experimental program of weather control sponsored by the Commission.

(2) Each license shall be issued for a specific period only, to be determined by the Commission, and may be revoked at any time by the State Engineer upon recommendation of the Commission.

SEC. 8. A fee of $100 shall be charged for each license issued.

SEC. 9. (1) Any person whose interest is substantially affected by any action of the Commission may request, in writing, a hearing before the Commission. Request for hearing shall be filed with the State Engineer within 20 days of the action of the Commission for which hearing is requested.

(2) Within 20 days after receipt of a request for hearing the Commission must set a date for the hearing which shall be held not less than 60 days after receipt of the request, at place designated by the Commission.

(3) All hearings shall be public and the person who requested the hearing may appear with counsel. Rulings made by the Commission at the hearing shall be final.

(4) Appeal may be taken from any final order of the Commission to the circuit court of Marion County.

SEC. 10. Any person who engages in weather-control activities in violation of this Act is creating a public nuisance.

SEC. 11. (1) Proceedings to abate public nuisances created by engaging in weather-control activities in violation of this Act may be instituted at law or in equity in the name of the State of Oregon, on behalf of the Commission, by the Attorney General.

(2) Whenever conditions are such as to require immediate action to protect the public health or welfare, the Commission may take any action deemed advisable for summary abatement of the nuisance.

SEC. 12. (1) Violation of any provision of this Act is punishable upon conviction by a fine not exceeding $1,000, or by imprisonment in the county jail for not more than one year.

(2) Any defendant who causes damage to the property of any plaintiff in violation of the provisions of this Act shall be liable for double the amount of damage caused.

SEC. 13. (1) Each member of the Commission and each member who serves by virtue of his office shall receive only the expenses actually and necessarily incurred in carrying out the duties required of them by this Act.

(2) Each appointed member of the advisory boards shall receive compensation at the rate of $10 per day for each day spent carrying out the duties required by this Act.

[H. B. No. 251, State of Colorado, Enacted]

AN ACT To assist and foster private or public research and development in artificial weather modification and to protect life, property, and public interest from injurious weather modification practices

SECTION 1. It is hereby declared that the State of Colorado claims the right to all moisture suspended in the atmosphere which would fall so as to become part of the natural streams of Colorado, for use in accordance with its laws; and also

the prior right to increase precipitation by artificial means for use in Colorado without material damage to others.

SEC. 2. The word "Commission" as used in this Act means the Weather Control Commission established by section 3 hereof.

SEC. 3. There is hereby established a "Weather Control Commission" composed of five (5) members to be appointed by the Governor immediately after passage of this Act, one member from each United States Congressional District in the State of Colorado and one member at large. When appointed, said Commissioners shall draw lots upon the basis of which one of them shall serve until May 1, 1952, one until May 1, 1953, one until May 1, 1954, one until May 1, 1955, and one until May 1, 1956. Thereafter appointments to fill vacancies, or upon the expiration of a term, shall be made by the Governor to fill successive five (5) year terms of the same classifications as hereinabove defined; the terms being so arranged that one new term commences each May 1 after 1956.

SEC. 4. The members of the Commission shall serve without pay, but shall be reimbursed for their expenses necessarily and reasonably incurred in connection with the performance of their duties as Commissioners.

SEC. 5. The Commission shall establish rules, regulations, and practices reasonably necessary to effectuate the purposes of this Act pursuant to the standards and within the limitations hereinafter set forth.

SEC. 6. The Commissioner of Agriculture shall issue all licenses provided for herein under rules and regulations established by the Commission. The State Engineer and those subordinate to him and the Commissioner of Agriculture are hereby authorized and directed to execute and administer all other provisions of this Act pursuant to regulations established by the Commission.

SEC. 7. No person, persons, or corporation shall, without having first secured a license therefor, conduct any weather control or cloud modification operations, or attempt artificially to control precipitation.

SEC. 8. Licenses to endeavor to modify weather by acts to be performed in Colorado shall be issued to applicants therefor who demonstrate:

(a) Financial responsibility adequate to meet obligations reasonably likely to be attached to or result from weather-control activities.

(b) Skill and experience reasonably necessary to accomplishment of weather control without actionable injury to property or person.

SEC. 9. Any person, persons, or corporation conducting any weather control or cloud modification operation or attempting artificially to produce precipitation in Colorado or elsewhere by undertaking operations within Colorado, shall report the place, method, type of material used, purpose, and area to be benefited of, by or through such operation, at such time or times and in manner and form as may be required by the Commission in order to aid in research and development in artificial weather modification and to aid in the protection of life and property.

SEC. 10. A license shall be issued hereunder only upon the payment to the State of Colorado of the sum of one hundred dollars ($100.00) for such license and shall expire at the end of the calendar year in which it shall be issued.

SEC. 11. The Commission shall revoke any license issued hereunder if it shall appear that such licensee no longer possesses the qualifications necessary for the issuance of a new license, or shall have been guilty of a violation of any of the provisions of this Act. Such revocation shall occur only after notice to such licensee and a reasonable opportunity granted such licensee to be heard respecting the grounds of such proposed revocation.

SEC. 12 Rulings by the Commission on the issuance, refusal, or revocation of a license shall be subject to review only in the District Court of the City and County of Denver or the Supreme Court of the State of Colorado; provided that findings of fact by the Commission shall be final and conclusive unless against the manifest weight of evidence adduced before the Commission.

SEC. 13. Weather control operations may not be carried on in Colorado for the purpose of affecting weather in any other State which prohibits such operations to be carried on in that State for the benefit of Colorado or its inhabitants.

SEC. 14. Any person, persons, or corporation conducting a weather control or cloud modification operation without first having procured a license, as herein provided, or who shall make a false statement in the application for a license, or who shall conduct any weather control or cloud modification operation after revocation of his, their, or its license, or who shall violate any other provision of this Act, shall be guilty of a misdemeanor, and upon conviction, if a person, shall be fined not more than $1,000 or imprisoned not more than sixty days, or both; and, if a corporation, shall be fined not more than $1,000. Each such violation shall be a separate offense.

SEC. 15. If any section, clause, phrase or word of this Act shall be declared unconstitutional for any reason, the remainder of this Act shall not be affected thereby.

SEC. 16. The General Assembly hereby finds, determines, and declares that this Act is necessary for the immediate preservation of the public peace, health, and safety.

[California Legislature—1951 Regular Session. Assembly Bill No. 101, Not Enacted]

AN ACT to amend Section 9 of the Riverside County Flood Control and Water Conservation District Act, relating to the powers of the Riverside County Flood Control and Water Conservation District

The people of the State of California do enact as follows:

SECTION 1. Section 9 of the Riverside County Flood Control and Water Conservation District Act is amended to read:

"SEC. 9. The objects and purposes of this act are to provide for the control of the flood and storm waters of said district and the flood and storm waters of streams that have their source outside of said district, but which streams and the said waters thereof flow into said district, and to conserve such waters for beneficial and useful purposes by retarding, spreading, storing, retaining and causing to percolate into the soil within said district, or without said district, such waters, or to save or conserve in any manner all or any of such waters and protect from such flood or storm waters, the watercourses, watersheds, public highways, life and property in said district, and to prevent waste of water or diminution of the water supply in, or unlawful exporation of water from said district, and to obtain, retain and reclaim drainage, storm, flood and other waters for beneficial use in said district.

"Riverside County Flood Control and Water Conservation District is hereby declared to be a body corporate and politic and as such shall have power:

"1. To have perpetual succession.

"2. To adopt a seal and alter it at pleasure.

"3. To sue and be sued in the name of said district in all actions and proceedings in all courts and tribunals of competent jurisdiction.

"4. To acquire, by purchase, lease, construction or otherwise, or contract to acquire, lands, rights-of-way, easements, privileges and property of any kind, whether real, personal or mixed, and to construct, maintain and operate any and all works or improvements within or without the district necessary, convenient or proper to carry out any of the objects or purposes of this act, and to complete, extend, add to, repair or otherwise improve any works or improvements or property acquired by it as authorized by this act; to indemnify or compensate any owner of land or other property for any injury or damage caused by the exercise of the powers conferred by this act.

"5. To take by grant, purchase, gift, devise or lease, or otherwise, and to hold, use, enjoy and to lease or dispose of real, personal or mixed property of every kind within or without the district necessary or convenient to the full exercise of its powers.

"6. To incur indebtedness, and to issue bonds in the manner herein provided.

"7. To store water in surface or underground reservoirs within or outside of the district for the common benefit of the district or a zone or zones thereof; to conserve and reclaim water for present and future use within the district; to appropriate and acquire water and water rights, and import water into the district and to conserve within or outside the district, same for any useful purpose to the district; to commence, maintain, intervene in and compromise, in the name of the district, or otherwise, and to assume the costs and expenses of any action or proceeding involving or affecting the ownership or use of water or water rights within the district used or useful for any purpose of the district or of common benefit to any land situated therein, or involving the wasteful use of water therein; to commence, maintain, intervene in, defend and compromise and to assume the cost and expenses of any and all actions and proceedings hereafter begun; to prevent contamination, pollution or otherwise rendering unfit for beneficial use the surface or subsurface water used in said district, and to commence, maintain and defend actions and proceedings to prevent any such interference with the aforesaid waters as may endanger or damage the inhabitants, lands, or use of water in the district; provided, however, that the said district shall not have the power to intervene or take part in, or to pay the costs or expenses of actions or controversies between the owners of lands or water rights within the boundaries of the district and which do not involve taking water outside or away from the district.

"8. To control the flood and storm waters of said district and the flood and storm waters of streams that have their source outside of said district, but which streams and the flood waters thereof, flow into said district, and to conserve such waters for beneficial and useful purposes within said district by retarding, spreading, storing, retaining and causing to percolate into the soil within or without said district, or to save and conserve in any manner all or any of such waters and protect from damage from such flood or storm waters the watercourses, watersheds, public highways, life and property in said district, provided that water rights now existing be not thereby infringed upon.

"9. To have and exercise the right of eminent domain, either within or without said district, and in the manner provided by law for the condemnation of private property for public use, to take any property necessary to carry out any of the objects or purposes of this act, whether such property be already devoted to the same use by any district or other public corporation or agency or otherwise, and to condemn, any existing works or improvements in said district now or hereafter used to control flood or storm waters or to conserve such flood or storm waters or to protect any property in said district from damage from such flood or storm waters, and it is hereby declared that the use of the property, lands, right-of-way, easements, or materials which may be condemned, taken or appropriated under the provisions of this act, is a public use subject to the regulation and control of the State in the manner prescribed by law; provided, however, that nothing in this act contained shall be deemed to authorize said district, or any person or persons to divert the waters of any river, creek, stream, irrigation system, canal or ditch, from its channel, to the injury or detriment of any person, or persons, having any interest in such river, creek, stream, irrigation system, canal or ditch, or the waters thereof or therein, unless compensation be first ascertained and paid therefor, under the laws of this State authorizing the taking of private property for public use; and provided further, that no right shall exist in behalf of said district to take by condemnation any property, including water rights, that is now devoted to beneficial use in Orange County; nor to take by condemnation any water rights or property necessary for exercising said water rights that are now devoted to beneficial use, or are now in the process of being devoted to beneficial use in Orange County, within an area along and adjacent to the trunk channel of the Santa Ana River extending from the easterly boundary of Orange County to the Jurupa Narrows and lying between the bluffs on either side of said river, but excluding therefrom any part of the Corona underground water basin as said basin is defined in that certain action in the Superior Court of the State of California, in and for the County of Riverside, numbered 22046, and entitled the Corona Foothill Lemon Company, a corporation et al. vs. Charles E. Lillibridge et al.

"The power of eminent domain vested in the board of supervisors of said district shall include the power to condemn in the name of the district with the fee simple or any lesser estate or interest in any real property which said board by resolution shall determine is necessary for carrying out the purposes of this act. Such resolution shall be prima facie evidence that the taking of the fee simple or any lesser estate or interest in such property, as the case may be, is necessary. Whenever real property which is devoted to or held for some other public or quasi-public use is required by the district for flood control or water conservation purposes, the district may condemn real property adjacent thereto or in the immediate vicinity thereof to be exchanged for the real property required by the district as aforesaid for flood control or water conservation purposes.

"10. To enter upon any land, to make surveys and locate the necessary works of improvement and the lines of channels, conduits, canals, pipelines, roadways and other rights-of-way; to acquire by purchase, lease, contract, condemnation, gift or other legal means all lands and water and water rights and other property necessary or convenient for the construction, use, supply, maintenance, repair and improvement of said works, whether in this or in another state, including works constructed and being constructed by private owners, lands for reservoirs, for storage of necessary water, and all necessary appurtenances, and also where necessary or convenient to said end, and for said purposes and uses, to acquire and hold the stock of corporations, domestic or foreign, owning water or water rights, canals, waterworks, power plants, franchises, concessions or rights; to enter into and to do any and all acts necessary or proper for the performance of any agreement with the United States, or any state, county, district of any kind, public or private corporation, association, firm or individual, or any number of them, for the joint acquisition, construction, leasing, ownership, disposition, use, management, maintenance, repair or operation of any rights, works or other property

of a kind which might be lawfully acquired or owned by said Riverside County Flood Control and Water Conservation District; to acquire the right to store water in any reservoirs, or to carry water through any canal, ditch or conduit not owned or controlled by the district; to grant any owner or lessee the right to the use of any water or the right to store such water in any reservoir of the district or to carry such water through any tunnels, canal, ditch or conduit of the district; to enter into and to do any acts necessary or proper for the performance of any agreement with any district of any kind, public or private corporation, association, firm or individual, or any number of them for the transfer or delivery to any such district, corporation, association, firm or individual of any water right or water pumped, stored, appropriated or otherwise acquired, or secured for the use of the Riverside County Flood Control and Water Conservation District, or for the purpose of exchanging the same for other water, water right or water supply to be delivered to said district by the other party to said agreement; to cooperate with, and to act in conjunction with the State of California, or any of its engineers, officers, boards, commissions, departments or agencies, or with the Government of the United States, or any of its engineers, officers, boards, commissions, departments or agencies, or with any public or private corporation, in the construction of any work for the controlling of flood or storm waters of said district, or for the protection of life or property therein, or for the purpose of conserving said waters for beneficial use within said district, or in any such works, acts, or purposes provided for herein, and to adopt and carry out any definite plan or system of work for any such purpose as authorized herein.

"11. To cause taxes and assessments to be levied and collected for the purpose of paying any obligation of the district and to carry out any of the purposes of this act, in the manner hereinafter provided.

"12. To carry on technical and other investigations of all kinds, make measurements, collect data and make analyses, studies, and inspections pertaining to water supply, water rights, control of floods and use of water, both within and without said district, and for such purposes said district shall have the right of access through its authorized representatives to all properties within said district.

"*13. To carry on a program of artificial nucleation for the purpose of increasing and controlling rainfall within, or in the immediate vicinity of, any watershed located wholly or partially within the district.*

"[13.] *14.* To make contracts and to employ labor and to do all acts necessary for the full exercise of all powers vested in said district, or any of the officers thereof by this act."

[California Legislature—1951 Regular Session. Assembly Bill No. 2706, Not Enacted]

AN ACT To add Section 17.1 to the State Water Resources Act of 1945, authorizing the State Water Resources Board to contract with public and private organizations and persons for research work relative to the production and control of rainfall by artificial means, and making an appropriation therefor

The people of the State of California do enact as follows:

SECTION 1. Section 17.1 is added to the State Water Resources Act of 1945, to read:

"SEC. 17.1. The Water Resources Board is authorized to contract with public and private organizations and persons for research [and experimentation] relative to the production and control of rainfall by artificial means.

"SEC. 2. There is hereby appropriated to the State Water Resources Board out of the General Fund in the State Treasury fifty thousand dollars ($50,000) to be expended in research [and experimentation] in the production and control of rainfall by artificial means."

[Senate Bill No. 986, Not Enacted]

AN ACT To provide for the licensing of persons engaging in the production and control of rainfall by artificial means

The people of the State of California do enact as follows:

SECTION 1. It is unlawful for any person to engage in the production and control of rainfall by artificial means without first obtaining a license therefor from the Department of Public Works, Division of Water Resources.

SEC. 2. The department may issue a license entitling a person to engage in the production and control of rainfall by artificial means for a period of one year, upon the payment of a reasonable annual fee, to be fixed by the department, if, in the judgment of the department, satisfactory proof is presented by the applicant

that he is of good character and possesses the necessary technical knowledge and ability to produce and control rainfall by artificial means.

SEC. 3. The department may make such rules and regulations as may be necessary to carry out the provisions of this act.

[Senate Bill No. 388, Not Enacted]

AN ACT To add Section 9.5 to the Riverside County Flood Control and Water Conservation District Act relating to the power of a district organized under the act to carry on an experimental program of artificial rain making and limiting the district's taxing power for this purpose.

The people of the State of California do enact as follows:

SECTION 1. Section 9.5 is added to the Riverside County Flood Control and Water Conservation District Act, to read:

"SEC. 9.5. The district may carry on an experimental program of artificial rain making, within any watershed located wholly or partially within the district and the immediate vicinity thereof, using any means therefor it deems feasible. No ad valorem tax or assessment upon taxable property levied pursuant to section 14 hereof for the above purpose shall exceed five mills ($0.005) on each one hundred dollars ($100) of assessed valuation."

[Senate Bill No. 617, Not Enacted]

AN ACT To provide for the regulation and licensing of interference or attempts to interfere by artificial means with natural condensation and precipitation of rain, snow, moisture or water in any form contained in the atmosphere; to provide for the enforcement of said act and penalties for the violation thereof

The people of the State of California do enact as follows:

SECTION 1. The public interest, health, safety, welfare and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop, increase and regulate natural precipitation be encouraged, and that means be provided for the regulation and control of interference by artificial means with natural precipitation of rain, snow, moisture or water in any form contained in the atmosphere, within the State of California, in order to develop, conserve and protect the natural water resources of this State and to safeguard life and property.

SEC. 2. Unless the context otherwise requires, the following definitions shall govern the construction of this act:

(a) "Department" means the Department of Public Works acting through the State Engineer.

(b) "Person" means any person, firm, association, organization, partnership, company, corporation, private or public, county, city, city and county, district, or other public agency.

(c) The singular number includes the plural and the plural, the singular.

(d) The masculine gender includes the feminine and the neuter.

(e) "Shall" is mandatory and "may" is permissive.

(f) The present tense includes past and future tenses, and the future, the present.

SEC. 3. No person, without first securing a license from the department, shall cause or attempt to cause condensation or precipitation of rain, snow, moisture or water in any form contained in the atmosphere, or shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, moisture or water in any form contained in the atmosphere.

SEC. 4. Any person desiring to do any of the acts specified in Section 3 of this act may file with the department an application in writing for a license. Each application shall be accompanied by a filing fee of $_____ and shall be on a form to be supplied for such purpose by the department.

SEC. 5. Every application shall set forth all of the following:

(a) The name and post-office address of the applicant.

(b) The previous education, experience and qualifications of the applicant, or, if the applicant is other than an individual, the previous education, experience and qualifications of the persons who will be in control of and charged with the operations of the applicant.

(c) A general description of the operations which the applicant intends to conduct and the method and type of equipment that the applicant proposes to use.

(d) Such other pertinent information as the department may require.

SEC. 6. Upon the filing of the application upon a form supplied by the department and containing the information prescribed by this act and accompanied by the required filing fee the department shall issue a license to the applicant entitling the applicant to conduct the operations described in the application for the calendar year for which the license is issued, unless the license is sooner revoked or suspended. Such license may be renewed annually upon application to the department, accompanied by a renewal fee of $_____, on or before the last day of January of the calendar year for which the license is renewed.

SEC. 7. Prior to doing any act or conducting any operation authorized by the license the licensee shall file with the department and cause to be published a notice of intention.

SEC. 8. The notice of intention shall set forth all of the following:

(a) The name and address of the licensee.

(b) The nature and object of the intended operation and the person or persons on whose behalf it is to be conducted.

(c) The area in which and the approximate time during which the operation will be conducted.

(d) The area which will be affected by the operation as near as the same may be determined in advance.

SEC. 9. The applicant shall cause the notice of intention to be published at least once a week for three consecutive weeks in a newspaper having a general circulation and published within any county wherein the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be caused to be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county publication shall be made in a newspaper having a general circulation within the county.

SEC. 10. Proof of publication shall be filed by the licensee with the department within 15 days from the date of the last publication of the notice. Proof of publication shall be by copy of the notice as published attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice.

SEC. 11. Every licensee shall keep and maintain a record of all of the operations conducted by him pursuant to his license showing the method employed, the type of equipment used, the times and places of operation of the equipment, the extent of the affected area, the effect upon natural condensation and precipitation as near as the same may be determined or estimated including the amount of precipitation resulting from the operation, if any, the name and post-office address of each person participating or assisting in the operation other than the applicant, and such other information as may be required by the department, and shall report the same to the department immediately upon completion of each operation and at such times as may be required by the department.

SEC. 12. Any license may be revoked or suspended if the department finds, after due notice to the licensee and a hearing thereon, that the licensee has failed or refused to comply with any of the provisions of this act.

SEC. 13. Any person who violates any provision of this act is guilty of a misdemeanor.

STATE OF NEW MEXICO

OFFICE OF THE SECRETARY OF STATE

Certificate

I, Beatrice B. Roach, Secretary of State of the State of New Mexico, do hereby certify that this is a true and correct copy of Senate Bill No. 219 which was passed by the Twentieth Legislature of 1951, as the same appears on the enrolled and engrossed copy on file in this office. Given under my hand and the Great Seal of the State of New Mexico, in the City of Santa Fe, the Capital on this 24th day of May 1951 A. D.

[SEAL]

V. CHRIS SANCHEZ,
Assistant Secretary of State.

[Twentieth Legislature, State of New Mexico. Senate Bill No. 219]

AN ACT Relating to nonprofit corporations organized for purposes relating to the study and analysis of annual precipitation and general weather conditions and the attempted increase of annual precipitation

Be it enacted by the Legislature of the State of New Mexico:

SEC. 1. The study and analysis of annual precipitation and general weather conditions and the attempted increase of annual precipitation are hereby declared to be beneficial and in the public interest, and the purpose of studying and analyzing such annual precipitation and general weather conditions and attempting to increase the annual precipitation is hereby declared to be a benevolent, charitable and scientific purpose.

SEC. 2. Incorporators desiring to form a nonprofit corporation for the purpose of studying and analyzing annual precipitation and general weather conditions and attempting to increase the annual precipitation may incorporate such corporation as a corporation for benevolent, charitable and scientific purposes pursuant to the provisions of sections 54–1306 to 54–1310, New Mexico Statutes 1941.

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